NUTRITIONAL STUDIES WITH

BOS TAURUS AND *BOS INDICUS* CALVES

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This thesis has been composed by me,

and it is a record of my own work.

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SUMMARY

Milk substitute diets whose dry matter contained 10%, 20% and 30% added fat were fed to Bos taurus calves in Scotland and Bos indicus and Bos taurus calves in Trinidad. Bos taurus calves adapted readily to the system of artificial rearing used, but considerable difficulty was experienced in training Bos indicus calves to drink either milk substitute or whole milk diets from a bucket, and as a consequence their daily intake of milk was considerably less than that of Bos taurus calves of comparable body weight. The food intake of Bos indicus calves was increased markedly by allowing them to suck milk from nurse cows, and under these conditions their intake was similar to that of Bos taurus animals of comparable body weight.

The apparent digestibility of the components of the milk substitute diets by Bos indicus and Bos taurus calves was similar irrespective of the fat content of these diets, but Bos indicus calves appeared to retain more magnesium than Bos taurus calves. This high level of magnesium retention may have resulted from the low rate of water intake and urine excretion by Bos indicus calves

and could have been responsible for the occurrence of urolithiasis in some of the Bos indicus calves. ~~for~~ Although none of the Bos taurus calves exhibited symptoms of urolithiasis, 33% of those Bos indicus calves which survived until weaning died within six weeks of weaning as a result of urinary calculi formation and the calculi obtained from those Bos indicus calves which died had a very high magnesium content.

The apparent digestibility of the components of the milk substitute diets was higher by Bos taurus calves in Trinidad than by Bos taurus calves in Scotland. This finding was most apparent when calves were fed the milk substitute diet containing 30% added fat. The use of this diet was discontinued in Scotland because a large percentage of the calves on this treatment died, but in Trinidad Bos taurus calves digested this diet without difficulty.

The digestible energy requirement for maintenance of each kilogramme of body weight was found to be considerably less for Bos taurus calves reared in Trinidad than for Bos taurus calves reared in Scotland.

The apparent digestibility of nitrogen by Bos indicus and Bos taurus calves in Trinidad was similar, but the digested nitrogen required for the maintenance of body weight was greater for _Bos indicus_ calves than for _Bos taurus_ calves, because of a high endogenous nitrogen excretion rate in urine by _Bos indicus_ calves.

With all calves the apparent digestibility of fat and the apparent absorption of calcium were positively correlated irrespective of the fat content of the diet fed. This presumably indicates that fatty acids excreted in the faeces were in the form of calcium soaps.

The heart rate of calves was shown to be affected by the fat content of the diet fed and the level of food intake, but _Bos taurus_ and _Bos indicus_ calves with similar levels of food intake had similar heart rates.

Partial alopecia was exhibited between five and eight weeks of age by all _Bos indicus_ calves, but by no _Bos taurus_ calf.

Under the conditions of this experiment, the major difference between _Bos indicus_ and _Bos taurus_ calves was the behavioural response by _Bos indicus_ calves to the system of artificial rearing practised which resulted in these calves having a low voluntary food and water intake. It is not clear to what extent this low voluntary food and water intake affected the other minor differences which were observed between those _Bos indicus_ and _Bos taurus_ calves used in these experiments, but no justification has been obtained that, in general, _Bos indicus_ calves differ from _Bos taurus_ calves in their nutrient requirements.

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1. INTRODUCTION

The earliest known type of wild cattle was the Bos acutifrons from which both Bos primigenius and Bos nomadicus were descended (Pilgrim, 1947). Domestication of these two species of cattle took place around 8000 B.C. The former are ancestors of present day Bos taurus cattle and the latter are ancestors of present day Bos indicus cattle. The origin of Bos brachyceros is not clear, but, at least in one centre of domestication (Anau, Turkestan) it is thought to have been either a mutant of Bos nomadicus or because of its comparatively small size the result of the unfavourable influence of domestication on the Bos nomadicus. Whatever its origin Bos brachyceros is thought to have played a part, along with the Bos primigenius in the evolution of the Bos taurus species of cattle, but it is generally accepted that the main ancestor of Bos taurus cattle was Bos primigenius.

Bos taurus, or European-type cattle and Bos indicus, or Zebu-type cattle are the two most important species of cattle in the world today and are classified in the subgroup Taurine of the genus Bos. Of a total world cattle population of approximately 1,200 million (F.A.O., 1973) it can be estimated, (based on the assumptions of Webster and Wilson, 1968) that approximately 650 million are of the Bos indicus species and the remaining 550 million are Bos taurus and crossbred cattle of the Bos taurus and Bos indicus species.

Assuming that 40% of the world Bos indicus population are cows aged two years and over (F.A.O., 1973) and that the average age at first calving of Bos indicus cattle is three years, then of a total Bos indicus population of 650 million, approximately 220 million will be sexually mature females. A calving percentage of 40% is normal in developing countries and this results in an annual Bos indicus calf crop of approximately 90 million of which 45 million will be female calves. The importance of this relatively small number of female Bos indicus calves as the foundation stock on which the future production from Bos indicus cattle will be based cannot be over-emphasised. At present, however, there are few recommendations, based on experimental work, of the management and nutritional requirements of the Bos indicus calf. Similarly, while there is much information available on the husbandry of the Bos taurus calf in a temperate climate, there is only limited information on the performance of this type of calf in a tropical climate.

The present systems of rearing Bos indicus calves in developing countries not only result in high calf mortality rates and poor growth rates, but also involve a large proportion of the milk produced being fed to calves. If a system of calf rearing based on minimal quantities of milk being fed to the calf can be developed, it is conceivable that a large proportion of milk and more specifically milk protein at present being used in calf rearing would be available to the human population.

In order to prevent a protein deficiency in adults, the daily per capita intake of dietary protein should be 70g. of which at least 20g. should be of animal origin (Lowry, 1970). Potentially one of the most readily available sources of animal protein is milk, and while in certain areas there is a deficiency of lactase in the digestive systems of humans (Kretchmer, 1973) and there are taboos, tastes and customs which restrict the consumption of milk by humans, the main reason why milk is not consumed to any large extent is because of its scarcity.

In India the per capita dietary protein supply is about 50g. per day, of which about 4g. is in the form of milk protein (Parpia, 1968). The additional 20g. of protein required daily to prevent protein deficiency symptoms could be supplied by the equivalent of an additional per capita consumption of 0.6 l. of milk daily in the form of whole milk or milk products. Where whole milk is available for consumption by the human population, the children of that population have the greatest need for this milk because it has been estimated that about 80% of children below the age of five years in developing countries may suffer from a protein deficiency characterised by kwashiorkor and marasmus (Parpia, 1968).

The advantages of using milk protein to offset dietary protein deficiencies are that it is readily palatable, is rich in essential amino acids, and would be available immediately to peasant farming communities without prohibitive distribution problems. Thus, information on the husbandry and nutrition of Bos indicus calves is urgently required both as a means of reducing calf mortality and of increasing the availability of milk for human consumption.

The purpose of this work is to provide information on management and nutritional requirements of both

Bos indicus and *Bos taurus* calves in a tropical environment with a view to improving calf growth performance using minimal quantities of milk and early weaning techniques.

2. REVIEW OF LITERATURE

2 : 1 Factors affecting calf growth rate

2:1:1 Calf birth weight and potential for protein deposition.

The effect of birth weight on the early post-natal growth rate of calves has been reported by many workers. With Black Pied cattle (Witt, Walter and Rappen, 1964) a correlation was found between birth weight and live weight at twelve months of age, and that for every 1.0kg increase in birth weight, there was a corresponding increase in live weight of 2.37kg at twelve months of age. Similarly, with Hereford and Aberdeen Angus calves with each change of 4.54kg in birth weight there was a difference in rate of live-weight gain of 52g per day until weaning at approx. 210kg. (Nelms and Bogart, 1956) Significant correlations of 0.51, 0.37, 0.44 and 0.44 have been reported between the birth weight and liveweight of Dutch Friesian cattle at 12, 24, 36 and 52 weeks respectively (Kassab, 1964).

Other workers, however, consider birth weight to be a poor indicator of future growth rate. In one experiment (Meyer, 1958), Black Pied bull calves were divided into eight groups according to their birth weight. The difference in relative live weights between group one (lowest) and group eight (highest) was 41.8% at one week of age, but the difference gradually diminished until at 24 weeks it was only 4.6%. Low correlations were also found between birth weight and growth rate to 90 and 210 days of age in Gir, Nellore, Indo-Brazilian and Gujarti calves (Torres, 1962). In both the above cases calves might not have been allowed to express their full potential for liveweight increase because of restricted food intake.

The effect of birth weight of Bos indicus calves on their growth rate has also been reported (Heyns, 1959). With Africander calves in one experiment every 4.54kg increase in birth weight was reported to result in an increased live weight after eight months of 41kg.

In general, the growth curve of animals is sigmoid in shape and consists of a self-accelerating phase of increasing slope and a self-inhibiting phase of decreasing slope. The two sections of the growth curve are joined at the time of puberty (Brody, 1945). For calves, only the self-accelerating phase need be considered and this can be represented by the equation

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$$W = Be^{+kt} \quad \text{(Roy, 1970a)}$$

where

W = Weight of calf at time t (kg)

B = Birth weight of calf (kg)

e = Base of the natural logarithms

t = Age in days

k = Instantaneous relative growth rate (100k = percentage growth rate)

The maximum growth rate for calves from birth to 91 days of age results in a value for k of about +0.0150, or a percentage growth rate of about 1.5% of live weight per day (Roy, 1970a). At this rate of gain the birth weight of calves will be doubled at approximately 50 days of age and by 91 days the live weight of the calf will be approximately 25% of its mature weight. This growth rate can, however, only be obtained under optimal nutritional and physical environmental conditions and in the absence of disease. To date it has not been confirmed that a value for k of 0.0150 represents the maximum growth rate that can be achieved by <u>Bos indicus</u> calves.

Growth curves were constructed for Friesian, Ayrshire and Jersey calves to 91 days of age to show the effect on live weight increase of feeding restricted and *ad libitum* levels of milk substitute intake by these calves (Roy, 1967). These curves indicated that the lower the mean birth weight of the breed, the lower was the absolute growth rate on both planes of nutrition. From the original growth curves adjusted growth curves were constructed to compare the three breeds of calves at similar birth weights. After this adjustment the Friesian breed had still a significantly greater exponent for growth than the Ayrshire and Jersey breeds at both levels of intake. From these adjusted growth curves, the values of k were +0.0136, +0.0124 and 0.0122 on the restricted level of milk substitute intake and +0.0159, +0.0135 and +0.0126 on the *ad libitum* level of milk substitute intake. These results indicate that birth weight was not the only factor involved in determining the growth rate of calves at both levels of intake.

In this work the other major factor investigated was nitrogen retention. This was determined from balance trials carried through on the same calves of these three breeds at the same live weight (65kg) and at 15% of mature weight. At 65kg live weight the amounts of nitrogen and calcium retained were higher for the Friesian breed than for the Ayrshire breed, and higher for the Ayrshire breed than for the Jersey breed. This result indicates that the younger the calf the higher the nitrogen and calcium retention. At 15% of mature weight nitrogen retention/ $W^{0.73}$ was the same for Ayrshire and Jersey breeds, but 20% higher for the Friesian breed both on the restricted and the ad libitum feeding systems. Calcium retention/ $W^{0.73}$ was the same for all three breeds. The Jersey and Ayrshire breeds therefore had a similar protein deposition ceiling and the Friesian breed a higher ceiling. Thus, at any given stage of maturity and on the same plane of nutrition calves of all three breeds should have the same fat to bone ratio, but Friesian calves should have a higher muscle to bone and muscle to fat ratio than both the other breeds.

From the above observation it can be concluded that when the physical and nutritional environment of the calf is adequate, the two main factors which affect the absolute growth rate of the calf are a) its birth weight, and b) its potential for protein deposition.

2:1:2 Interaction between the birth weight and the appetite of the calf and the milk production of the dam.

Birth weight <u>per se</u> probably has little effect on growth rate of calves and the influence of birth weight on growth rate is more likely to arise from the close association between the birth weight and the appetite of the calf.

It has been shown (Heyns, 1960) that for every additional 4.54kg increase in birth weight calves consumed an extra 454kg of milk over an eight month suckling period. The reason given for this increase was that the larger calf, having a greater appetite, resulted in a more complete emptying of the udder which, in turn, provided stimulus for milk secretion. The conclusion that milk production of the dam is limited to the capacity of its calf to consume milk, was reached previously (Gifford, 1949 and 1953) and supported by other workers (Melton, Cartwright and Nelson, 1967) who showed that the amount of milk given by the dams of bull calves was in excess of that given by the dams of heifer calves. In work mentioned previously (Heyns, 1959) the estimated milk yield of the dam of calves weighing more than 31.82kg was

was 1520 litres, while that for the dams of calves weighing less than 31.82kg was 1115 litres.

All the above correlations between calf birth weight and dam milk yield, however, presuppose that the dam has the ability to produce sufficient milk to satisfy the appetite of the calf. In areas where the nutritional status of the cow is poor, the influence of calf birth weight on calf growth rate is reduced, but growth rate is still closely correlated with milk production of the dam. This correlation was shown to exist with West African Shorthorn, N'Dama and Sokoto calves in Ghana (Montsma, 1960), where calves were suckled by their dams three times daily over a six month period including the dry season. Total milk production per animal was estimated by weighing calves before and after suckling and this varied from 290 to 720 litres. A correlation coefficient of 0.96 was obtained between the milk yield of the dam and growth rate of the calf to eight weeks and during this period the consumption of 45.45kg of milk resulted in 5.64kg increase in calf live weight.

As lactation proceeds and as the calf becomes accustomed to foodstuffs other than milk the correlation between calf birth weight and milk production of the dam decreases. In one experiment, it was shown that calf birth weight and dam milk production were correlated 0.43, 0.29 and 0.12 for the first, third and six month of lactation respectively (Drewry, Brown and Honea, 1959). Similarly the correlation between calf growth rate and dam milk production declined as lactation progressed (Melton, Cartwright and Nelson, 1966).

Also, with Hereford calves (Neville, 1962) 66% of the total variation in 240 day liveweight was attributed to differences in milk consumption, the relationship between milk consumption and calf live weight gain being greater during the first 60 days of life than thereafter. In other work, in which Bos indicus calves were used, birth weight accounted for only 26% of the total variation in weaning weight (Kohli, Suri, Bhatnagar and Kumar, 1962). In this work presumably the calf was not able to satisfy its appetite because of the low milk yield of Bos indicus cattle, and therefore the live weight advantage of the heavier calves at birth could not be maintained. Because of their dual purpose role, the lactation length of Bos indicus cattle which are used for milk production is probably less than that of Bos taurus cattle which are used for milk production. Therefore it is not surprising that where calves are fed milk from their dams for a period up to 240 days the correlation between calf growth rate and dam milk production should decline more rapidly in Bos indicus than in Bos taurus cattle, the calves of the former species being forced, through limited milk intake, to obtain nutrients from other sources.

In this context the milk production potential of Bos taurus and Bos indicus cattle is important. *

In Israel the national average milk production of Friesian cattle is over 4,500kg per cow per lactation with some herds exceeding 6,000kg per cow per lactation (Skjervold, 1967). With unselected Bos indicus, however, the potential for milk production has been quoted as being limited to approximately 1,000kg per cow per lactation (Williams and Bunge, 1952; Joshi, McLaughlin and Phillips, 1957; Lampkin and Lampkin, 1960; Mason and Maule, 1960; Galukande, Mahadevan and Black, 1962; Mahadevan, 1965; Mahadevan, 1966). Even lower values for milk production by Bos indicus cattle have been

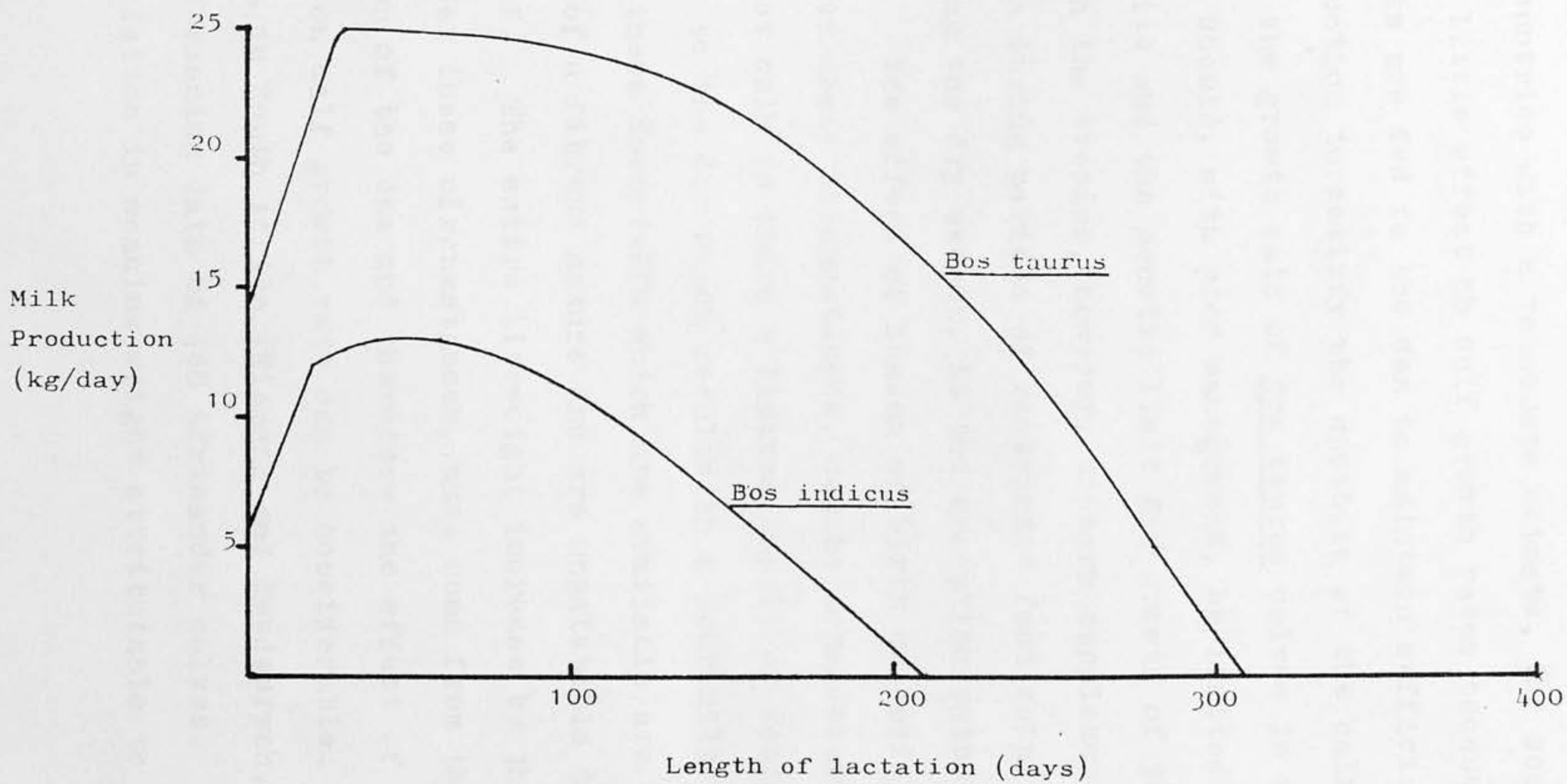
* Any comparison of the potential for milk production between Bos indicus and Bos taurus cattle is misleading because while specific breeds of the Bos taurus species are renowned for their ability to produce milk Bos indicus animals are, in general, dual purpose animals. In view of the dual purpose role they play it is unlikely that the potential for milk production by Bos indicus cattle has been exploited fully. An awareness of this situation is necessary in order that the correct interpretation is made of the milk production estimates quoted.

reported in Cuba, (Wollner, quoted by Preston and Willis, 1970a). In this work Brahman cows, managed as dairy animals, had an average milk production of only 2kg per day over a seven month lactation. *

With these low lactation yields by Bos indicus animals it must be assumed that the Bos indicus calf does not receive sufficient milk to realise its potential for growth if the milk of its dam is the only acceptable foodstuff available to it. This must be true, in particular, when Bos indicus calves are suckled by their dams for a period of up to nine months. On the other hand, sufficient milk should be available to Bos taurus calves to allow them to satisfy their appetite.

* In Fig. 2:1 an indication of the milk production by Bos indicus and Bos taurus cattle of the dairy type is given.

Fig. 2:1 Estimated lactation curves of Bos indicus and Bos taurus (dairy-type) cattle.



2:1:3 Influence of season of birth on calf growth rate.

In countries with a temperate climate, the season of birth has little effect on calf growth rates because supplements are fed to the dam to maintain sufficient milk production to satisfy the appetite of the calf. Therefore the growth rate of Bos taurus calves in these countries should, with good management, be limited by the appetite and the genetic limit for growth of the calf. In the tropics, however, dietary supplementation of the dam during periods of restricted food supply, e.g. during the dry season, is the exception rather than the rule. The effect of season of birth on calf growth rate, under these circumstances, can be considerable because not only is there a limited supply of foodstuffs available to the dam which results in a poor milk yield, but also these foodstuffs which are available are normally of a fibrous nature and are unpalatable to the young calf. The entire liveweight increase by the calf, under these circumstances, must come from the milk production of the dam and therefore the effect of season of birth on calf growth rate can be considerable. This was shown in South Africa (Niemann and Heydenrych, 1965) using pre-weaning data of 448 Africander calves. The total variation in weaning weight attributable to season of birth, birth weight, age of dam and weight of dam at calving were 49.9, 11.7, 37.2 and 1.2% respectively. Similarly, when Indo-Brazilian, Nellore, Giyarate and Gir cattle were grouped according to the quarter of the year in which they were born, differences in live weight gain were apparent between groups (Mattoso, 1961).

The magnitude of the influence of season of calving on calf growth rate is, however, only a function of animal management and in particular animal nutrition (Chieffi, Andrease and Veiga, 1950). This was concluded from work in Brazil with Gir, Nellore and Indo-Brazilian calves where the influence of season of calving on birth weights, 12 month weights, and 24 month weights of these calves could be eliminated through improved management and nutrition.

2:1:4 Genetic potential of calves for growth.

The genetic potential of calves for growth has already been mentioned as being approximately 1.5% of live weight as live weight increase per day during the first 91 days of life. While this growth rate has not been confirmed with <u>Bos indicus</u> calves an attempt has been made to assess the potential for growth by <u>Bos indicus</u> cattle in Uganda (Ankole, Nganda, Mbarara and Entebbe Zebus) during the first six months of life

(Marples, 1962). In this work the daily live weight increase was found to be 409g. Higher daily live weight increases were subsequently recorded for Brahman and Santa Gertrudes heifer calves (De Alba, Munoz and Edwards, 1963). Birth weights for these calves were 25.9 and 31.6kg respectively and their average live weight increase from birth to weaning at 240 days was 606 and 693g respectively. Over a similar period (240 days) the normal average daily growth rate for female Jersey calves having a birth weight of 22.7kg would be 581g and for Friesian calves with a birth weight of 42.2kg it would be 754g (Morrison, 1956). The growth of Brahman heifers mentioned above is therefore within the range quoted as being normal for Bos taurus calves.

Comparative studies to assess the potential for growth of pre-ruminant Bos taurus and Bos indicus calves in the same environment with the same management have not been carried out. There is therefore no evidence to suggest that the potential for growth is lower in Bos indicus than Bos taurus calves.

2:1:5 Animal health and management.

In countries with a temperate climate the calf is exposed to diseases such as white scour, joint-ill or navel-ill, pneumonia, calf diptheria, salmonellosis, coccidiosis, and diseases associated with helminths. In countries with a tropical climate, the calf is exposed not only to these diseases but also to tick-borne diseases such as Heartwater, Anaplasmosis, Red Water Fever and East Coast Fever. Whenever any of these diseases is contracted the appetite of the calf is affected and there is a reduction in food intake and, consequently, a reduction in growth rate. However, no absolute values of the extent of this reduction are available.

In areas where the calf is at risk from any of the diseases mentioned, the management of the calf under hygienic conditions is vital in reducing the population of the disease-causing bacteria, viruses and protozoa and in reducing the population of the vectors which transmit these diseases. The influence of disease on the calf will be discussed more fully in the section dealing with calf mortality. (section 2:5)

2:2 The influence of poor nutrition in early post-natal life on the later productivity of cattle.

It has been shown that prolonged under-nutrition in the first eight to twelve months of life causes "stunting" in cattle

(Brookes and Vincent, 1950; Crighton, Aitken and Boyne, 1959). Also, calves over three months of age after being fed only a maintenance ration for two to six months show compensatory growth when fed a diet containing sufficient nutrients to allow compensatory growth to take place (Hughes, Alder and Redford, 1955; Win chester and Howe, 1955; Winchester and Ellis, 1956).

In more recent work (Wardrop, 1966) Friesian and Hereford X Friesian calves, reared to gain weight at a rate of 0.875% of live weight per day during the first 13 weeks of life, showed no compensatory growth to allow them to catch up, during the first year of life, with control animals gaining weight at slightly over one per cent of live weight per day during the first 13 weeks of life. Both groups of animals were weaned at 13 weeks and fed a commercial calf starter ration <u>ad libitum</u> to enable compensatory growth to take place.

The results of this experiment are in agreement with those mentioned above (Brookes and Vincent, 1950) to the extent that the plane of nutrition during the milk-feeding period had an effect, at least up to one year of age, on the liveweight of the animals. The main difference between these two experiments is that whereas in the earlier work (Brookes and Vincent, 1950) under-nutrition during the first eight months of life had a permanent effect on body weight the later work (Wardrop, 1966) showed that under-nutrition during as short a period as the first 13 weeks of life resulted in a prolonged and possibly permanent effect on body weight. Based on even more recent unpublished findings, the later worker further suggested that the critical period for the calf may be during the pre-ruminant stage, i.e. between birth and three weeks of age. Short periods of under-nutrition in early life have already been shown to cause permanent "stunting" in sheep (Schinckel and Short, 1961) and in rats (Schultz, 1955; Widdowson and Kennedy, 1962).

If the suggestion of Wardrop (1966) is confirmed experimentally, it follows that all factors which might retard the growth rate of calves during the first three weeks of life should be eliminated if maximum growth rates are to be achieved.

2:3 The nutrition of the pre-ruminant calf

2:3:1 The reflex closure of the oesophageal groove.

The young calf is regarded as having monogastric digestion because the rumen, reticulum and omasum, the first three compartments of the compound stomach of ruminants, do not develop fully and assume their characteristic digestive functions until the young calf begins to ingest substantial quantities of solid food (Ash, 1964). When the young calf swallows milk, nearly all of it by-passes the reticulo-rumen and flows rapidly through the omasum into the abomasum as a result of the reflex closure of the oesophageal groove.

The reflex closure of the oesophageal groove occurs when the soluble proteins and salts of milk are ingested (Webster, 1930); 60 ml of a ten per cent solution of sodium bicarbonate being the solution most effective in causing closure (Riek, 1954). Stimulation of the glossopharyngeal nerve also causes closure (Comline and Titchen, 1951). Until about eight weeks of age, ingestion of water also causes closure of the oesophageal groove, but is less effective than the stimulus resulting from the ingestion of milk and after eight weeks of age the stimulus from the ingestion of water becomes even less effective in causing closure. A wide variation exists between calves in their response to various stimuli on the reflex closure of the oesphageal groove, but in all calves the effect of stimuli decreases with age.

During the first four weeks of life the diet of the calf is normally in liquid form and in this form the only nutrients that can be utilised satisfactorily by the calf are milk proteins, butterfat, vegetable and other animal fats, lactose and glucose.

2:3:2 Digestion of organic matter by the pre-ruminant calf.

2:3:2:1 Protein digestion.

After ingestion by the calf, milk clots within one to ten minutes (Mortenson, Espe and Cannon, 1935). Under in vitro conditions abomasal secretion has been shown to promote the clotting of forty times its own volume of whole milk within three to 120 seconds, the clotting activity being greatest, because of a low pH, when the abomasal secretion is removed in the immediate pre-sucking and sucking periods (Ash, 1964).

As digestion in the abomasum proceeds, the clot breaks up and the nature of the chyme passing into the duodenum changes, three to four hours after feeding, from a whey-like fluid containing predominantly carbohydrates and soluble nitrogenous compounds, to a thick white opaque material containing protein and fat.

The total volume of chyme leaving the abomasum is about twice the volume of milk fed because of the continuous addition of saliva and abomasal secretions (Porter, 1969). The rate of passage of chyme from the abomasum is related to the volume of the abomasal contents, with an increased flow after feeding determined largely by the increase in the volume of the abomasal contents caused by feeding (Mylrea, 1966).

The enzymes responsible for the clotting of milk are the endopeptidases rennin and pepsin. It was originally thought that only rennin was responsible for the clotting of milk in the abomasum of the milk-fed calf, and that pepsin was not secreted in significant quantities until at least four weeks of age or until rumination had been encouraged in the calf by the ingestion of dry food (Berridge, Davis, Kon, Kon and Spratling, 1942-44). More recent experiments (Henschel, Hill and Porter, 1961) indicate that the young calf may secrete either or both rennin and pepsin and that the type of enzyme secreted is not predictable from the age of the animal or the nature of its diet.

Hydrochloric acid is also secreted in the abomasum, the rate of secretion being increased by the presence of milk in the abomasum (Mylrea, 1966). The pH of abomasal contents 14 hours after the feeding of milk has been shown to decrease with age, being 3.5 at one day of age and 2.9 by five weeks of age (Huber, 1969). Also, four hours after feeding, a pH of 4.1 in newborn calves fell to 3.4 at 16 days of age (Kesler, Ronning and Knodt, 1951).

Exocrine secretions from the pancreas are a major source of proteolytic, amylolytic and lipolytic enzymes; exocrine flow rates in calves increasing by a factor of six between four days and 100 days of age (McCormick and Stewart, 1967). This helps to explain why the components of a milk substitute diet although being relatively well digested by the young calf are digested more efficiently with increasing age of calf (Noller, Ward, McGilliard, Huffman and Duncan, 1956). In other work total protease activity of pancreatic tissue from calves on milk diets was lowest when calves were one day old, but nearly tripled by the time calves were eight days old and thereafter remained constant until the calves were 42 days old (Huber, Jacobson, Allen and Hartman, 1961).

2:3:2:2 Fat digestion.

Immediately after feeding some fat passes into the duodenum, but most of it is held within the caesin clot. Within 30 minutes of feeding about 50% of this fat remaining in the abomasum is hydrolysed, presumably by pre-gastric esterase as it has been shown (Toothill, 1975), that no lypolytic enzyme is secreted by the abomasum. This pre-gastric esterase has been shown to have preferential action on butyrate groups of triglycerides (Ramsey, 1962; Otterby, Ramsey and Wise, 1964; Grosskopf, 1965; Stewart and Otterby, 1968) at an optimum pH between 4.5 and 6.0. Six hours after feeding there is a considerable increase of fat movement from the abomasum to the duodenum associated with the disintegration of the curd (Termouth, Roy and Siddons, 1974).

Intestinal digestion of fat is brought about by pancreatic lipase, the activity of which increases with age (Termouth, Siddons and Toothill, 1971) and which is responsible for the hydrolysis of fat. After absorption, the majority of fatty acids containing more than ten to twelve carbon atoms are transported through the lymphatic system (Wadsworth and Shannon, 1971); the rate of lipid flow through the lymphatic system corresponding to the rate of release of fat from the casein curd (Shannon and Lascelles, 1967, 1967; Gooden, Brandon, Hartmann and Lascelles, 1972).

2:3:2:3 Carbohydrate digestion.

Lactase activity is high at birth and declines with age, but even at eight weeks of age lactase activity is ten times that in the adult animal (Seddons, 1968). Lactose has been shown to be almost completely utilised in liquid rations by young calves (Larsen, Stoddart, Jacobson and Allen, 1956; Dollar and Porter, 1957; Raven and Robinson, 1958; Thomas and Johnson, 1959; Velu, Kendall and Gardner, 1960; Huber, Jacobson, McGilliard, Morrill and Allen, 1961). The lactose content of the diet fed to calves has an effect on the lactase activity in the intestine of calves. By rearing calves on whole milk supplemented with 15% lactose, a three-fold increase in intestinal lactase was observed compared with the intestinal lactase activity in those calves receiving the unsupplemented diet. Doubling the lactose content in the milk did not decrease efficiency of utilization. However, when the lactose content in the milk was quadrupled overall digestive efficiencies decreased and fermentative diarrhoea developed (Huber, Rifkin and Keith, 1964). In other work using skim milk diarrhoea was induced in calves by adding sufficient lactose to double the intake of this sugar provided by skim milk (Rojas, Schweigert and Rupel, 1948). Apparently, therefore, a greater amount of lactose can be added to a whole milk diet compared with a skim milk diet before the calf shows symptoms of diarrhoea. Similarly, the feeding of skim milk containing glucose at the level of 30% of dry matter induced diarrhoea (Mathieu and deTugny, 1965). Later, Walker and Faichney (1964) suggested that 9g hexose/kg live weight/day as the level beyond which further additions are likely to induce diarrhoea in calves. However, 12g hexose/kg live weight/day can be fed if the fat intake of calves is at least 5.5g/kg live weight/day (Roy, 1969).

Sucrose is very poorly digested by the calf (Okamoto, Thomas and Johnston, 1959; Velu, Gardner and Kendall, 1959) as no intestinal sucrase activity has been observed in the calf (Dollar and Porter, 1957). More recent work (Raven, 1970) has shown that sucrose may serve as a suitable source of carbohydrate in milk substitute diets for calves, but only if it is included along with a suitable source of invertase. Despite the absence of intestinal sucrase, less than one half of the sucrose added to liquid diets of calves is recovered in the faeces (Huber, Jacobson, McGilliard and Allen, 1961; Henschel, Hill and Porter, 1963). In calves fitted with re-entrant ileal fistulae it was shown that about half of the unrecovered sucrose disappeared in the small intestine and the remainder in the caecum and large intestine (Morrill, Jacobson, McGilliard and Hotchkiss, 1965). In other work, about 60% of the sucrose fed through a duodenal fistula was not degraded by the time it reached the caecum, but that active fermentation in the caecum and colon occurred (Henschel et al, 1963). The disappearance of sucrose therefore may be the result of the action of micro-organisms in the lower gut, though small amounts may be absorbed intact since C^{14} sucrose was found to be present in the urine of calves given this sugar (Xenoulis, Jacobson, McGilliard and Allen, 1967).

The earliest reported digestibility of starch by young calves was in 1918 (Shaw, Woodward and Newton, 1918). In this work the digestibility of starch by two-day old calves was 23% increasing to 98% for 40-day old calves. Others have shown an increase in the apparent digestibility of starch with age (Jacobson, Allen and Bell, 1951; Noller, Ward, McGilliard, Huffman and Duncan, 1956). The action of micro-organisms on starch is considered the main reason for the high digestibilities reported by these workers as pancreatic amylase and intestinal maltase are only present in low concentrations in the young calf (Roy, 1970b). Small increases in the blood glucose response to starch ingestion have also been noted to increase with age in calves (Huber, Jacobson, McGilliard and Allen, 1961). Small increases have been reported in pancreatic amylase and intestinal maltase between three and eight weeks of age (Dollar and Porter, 1957) and the blood glucose response to maltose was twice as high at seven weeks as at three weeks (Huber et al., 1961). In a review of the literature, Preston (1958) concluded that starch is poorly used by very young calves and that for the first month of life lactose and glucose are the only carbohydrates suitable for inclusion in a milk substitute diet.

2:3:3 Protein and energy requirements of the pre-ruminant calf.

2:3:3:1 Protein requirement for maintenance and production.

It is claimed (Roy, 1970c) that the requirement by the calf for apparently digested crude protein (R_{ADP}) can be estimated from the following formula -

$$R_{ADP} = 6.25 \left[\frac{1}{BV.} (E + G + M.D) - M.D. \right]$$

where BV = biological value of the protein (as a coefficient)

E = endogenous urinary nitrogen (g/day)

G = nitrogen retention for a particular weight gain (g/day)

M = metabolic faecal nitrogen excretion (g/kg dry matter ingested)

D = dry matter intake (kg)

When the protein source is milk, a more accurate value would be obtained by using the factor 6.38 instead of 6.25. This is because both casein and albumen which together contain over 90% of the nitrogen in milk each contain 15.68% nitrogen (Davis and McDonald, 1953). Thus the requirement of the calf for digestible crude protein is affected by several factors and the details of these effects are given below.

The biological value of a protein is that proportion of the digested protein which is retained by the animal and in the pre-ruminant calf as with monogastric animals, the biological value reaches its maximum when the supply of amino-acids from the protein are in exactly the correct proportions for the requirement of the calf. Also the maximum biological value will only be obtained when the diet fed to the calf is limiting in protein (i.e. when there is an excess of energy and all other nutrients except protein).

The biological value of milk protein can be as high as 80% (Blaxter and Wood, 1952; Brisson, Cunningham and Haskells, 1957).

The endogenous urinary nitrogen per unit of body weight declines with age and has been reported as being within the range 63 to 82mg N/kg body weight/day (Blaxter and Wood, 1951a; Shillam and Roy, 1963; Roy, Gaston, Shillam, Thompson, Stobo and Greatorex, 1964).

With calves the amount of nitrogen stored for each kilogramme gain in live weight is within the range 26 to 34g (Blaxter and Wood, 1951a; Whitelaw, Preston and Nolumber, 1961; Roy et al., 1964; Stobo, Roy and Gaston, 1967). The absolute maximum amount of nitrogen stored each day appears to be a characteristic of the mature weight of the breed and its muscle: bone ratio (Roy, 1967).

The metabolic faecal nitrogen loss by the pre-ruminant calf fed whole milk or a good quality milk substitute has been shown to be approximately 1.9g N/kg dry matter intake (Roy et al., 1964).

Based on this information and using the formula provided, the requirement for apparently digested crude protein can be estimated for calves of various weights gaining weight at different rates.

A number of studies have indicated that the dry matter of milk substitutes should contain about 20% high quality protein (Cunningham, Haskell, Miles, Logan and Brisson, 1958; Lassiter, Brown, Grimes and Duncan, 1963). In more recent work, increasing the energy content of a milk substitute diet by increasing the concentration of fat from one to 29% of the dry matter had no effect on nitrogen retention, whereas reducing the protein concentration from 26-29% to 19% had a marked effect in reducing nitrogen retention from 26g/day to 19g/day in four-week old calves, and from 27g/day to 16g/day in ten-week old calves (Stobo, Roy and Gaston, 1967; Roy, Stobo, Gaston and Greatorex, 1970). The authors concluded that the level of 19% protein in the diet they used was sufficiently low for protein to be the limiting factor for growth.

Minimum crude protein contents (as a percentage of dry matter) in milk substitute diets for calves have been calculated for various levels of live weight increase (Roy, 1970d). (Table 2.1)

<u>Table 2:1</u>

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Table 2:1

Minimum crude protein content (%DM) required in milk substitute diets for calves (after Roy, 1970d)

Live weight (kg)	Maintenance	Maintenance +0.5kg gain per day	Maintenance +1.0kg gain per day
20	6.5	27.5	-
40	6.0	21.0	27.0
60	5.0	17.0	23.5
80	5.0	14.5	20.5
100	4.5	13.0	17.5

Two important points emerge from this table.

1. The greater the live weight gain required, the higher the protein content of the diet must be.

2. The lighter the calf the greater the protein content of the diet must be to obtain a particular live weight increase.

This is in agreement with other workers (van Weerden and van Hellemond, 1967) who found that, with veal calves, lowering the protein content of a milk substitute diet from 25 to 23% at five weeks of age and from 23 to 20% at nine weeks of age had no marked effect on calf growth rate and feed conversion ratio.

2:3:3:2 Amino acid requirement.

Individual amino acids appear to be utilised well by the pre-ruminant calf, but interpretation of their availability is difficult because of the unknown degrees of degradation and synthesis of amino acids which occur in the intestinal tract of calves. Availability of amino acids should therefore only be considered as an estimate of the net absorption of amino acids. In an experiment where the apparent availability to calves of 16 amino acids was determined over a period of 18 days beginning when calves were six days of age, it was found that methionine had a particularly low availability (11%) compared with the mean for the other 15 amino acids investigated (75%) (Radostits and Bell, 1968). In this work it was concluded that calves were deficient in methionine throughout the period of the digestibility trial. This conclusion is supported by the fact that in this work the methionine content of the dietary crude protein was 0.43% while in more recent work (Patureau-Mirand, Prugnaud and Pion, 1974) it has been suggested that the methionine requirement of pre-ruminant calves is about 3.5% of the dietary protein content. Also, in the later work, it was suggested that the cystine content of the dietary crude protein should be 0.9%.

2:3:3:3 Energy requirement for maintenance and production.

The ratio of digestible protein (in grammes) to digestible energy (in kilocalories) of calves declines sharply as the rate of live weight gain increases (Jacobson, 1968). At maintenance, maintenance +0.5kg gain, and maintenance +1.0kg gain, the ratios are 1:75, 1:35 and 1:29 respectively. Since the corresponding ratio for whole milk, containing 3.7% fat, is approximately 1:23 the growth rate of calves fed milk is more likely to be limited by energy intake than by protein intake.

When a milk substitute diet is fed to calves, the percentage of the digestible energy that must be supplied as protein increases as the rate of growth increases. For maintenance, maintenance +0.5kg gain, maintenance +1.0kg gain, and maintenance +1.5kg gain per day it was shown that the percentage digestible energy required as protein was 11.6, 17.0, 18.9 and 20% respectively for calves weighing 50kg and 10.0, 13.5, 15.6 and 16.9% respectively, for calves weighing 100kg (Roy, 1964). Similarly, in whole milk about 26% of the calories are derived from protein, but when sufficient energy is supplied to the calf from non-protein sources, to cover its maintenance requirements as little as 7% of the calories are necessary as protein. To achieve a live weight gain of 1.0kg/day, however, 22% of the calories must be obtained from protein (Blaxter and Wood, 1951a).

The energy requirement of the calf can be sub-divided into that required for maintenance and that required for growth. The maintenance requirement of the calf consists of the energy used for its basal metabolism, including a small loss of energy in the urine, together with the heat produced by voluntary activity.

Reported values for the basal metabolism in the pre-ruminant calf vary from 120 kcal/$W^{0.73}$ to 150 kcal/$W^{0.73}$ at one month of age (Ritzman and Colovos, 1943; Blaxter and Howells, 1951; Blaxter and Wood, 1951a; Blaxter and Wood, 1951b; Huffman and Reineke, 1957). The net availability of metabolisable energy from whole milk for maintenance has also been shown to vary from 79.5 to 84.5% (Blaxter, 1952; Gonzalez-Jimenez and Blaxter, 1962). Based on these figures, the maintenance requirements of the pre-ruminant calf in terms of metabolisable energy can be calculated as varying from 142.0 to 188.7 kcal M.E./$W^{0.73}$. This is in agreement with the requirement of 165.0 kcal ME/$W^{0.73}$/day suggested by the Agricultural Research Council (1965).

Recent work in Rhodesia (Johnson and Elliot, 1972a and b) has, however, indicated that the A.R.C. values may over-estimate the energy requirement by the pre-ruminant calf for maintenance and instead suggest that the maintenance requirement may vary from 100.8 to 110.1 kcal ME/$W^{0.73}$.

There are two possible reasons why the estimated metabolisable energy required by calves for maintenance was less in Rhodesia than in the U.K.

(i) Possibly less energy was used by animals in Rhodesia for thermal regulation than in the U.K. because of the difference in environmental temperature between locations.

(ii) The method of calculating metabolisable energy requirements for maintenance in the Rhodesia work was by the comparative slaughter technique, while the data from which the A.R.C. calculated basal metabolic rate were obtained from studies in which the efficiency of use of dietary energy by calves was obtained either from calorimetric studies or from experiments in which live body weight was used as a measure of response to dietary treatment. The comparative slaughter technique is probably the most accurate method of estimating these maintenance requirements.

On the basis of data derived from three studies (Blaxter and Wood, 1951a; Cunningham and Haskell, 1957; Bryant, Foreman, Jacobson and McGilliard, 1967) Jacobson (1968) calculated the mean requirements of the 50kg pre-ruminant calf for digestible energy as 47 kcal per kilogramme live weight per day for maintenance and 3300 kcal per kilogramme live weight gain.

2:3:4 Sources of protein and energy in diets for the pre-ruminant calf.

The protein component of milk substitute diets for calves is normally made up, almost entirely, from skim milk solids. Protein from sources other than milk have been used in milk substitute diets; the one most commonly used being soya bean protein. When this protein has been used results, in the form of live weight increase, have been disappointing allegedly due to the presence of trypsin inhibitor (Gorrill, Thomas, Stewart and Morrill, 1967; Gorrill and Thomas, 1967). More recently it has been claimed that acid or alkali treatment of soya flour markedly improves its utilization by the calf (Colvin and Ramsay, 1968 and 1969). If milk protein in milk substitute diets is eventually replaced by soya bean protein then carbohydrates may have to be added to the diet to replace the lactose of skim milk. However, if skim milk is used in milk substitute diets sufficient carbohydrate should be available to the calf and the quality of the dietary protein should always be adequate for the needs of the calf, provided that the processing of the milk substitute does not result in the denaturation of the whey proteins by overheating.

The lactose content of skim milk solids is about 51% (Davis and McDonald, 1953). As already mentioned the inclusion of additional lactose to a milk substitute diet predisposes the calf to fermentative diarrhoea (Huber et al., 1964) and therefore another source of energy must be used to replace butterfat. A convenient method of supplying calves with energy is to include fat in their diet because of the relatively high gross energy value of fat. Fat has more than twice the gross energy value of carbohydrates and the gross energy value of proteins is intermediate.

Table 2:2

Gross energy values of different nutrients
(dry matter basis)
(After Maynard and Loosli, 1956)

Nutrient		Gross energy (kcal/g)
Carbohydrate	(mean)	3.98
Fat	(mean)	9.34
Protein	(mean)	5.82

The difference in the gross energy values of these nutrients is governed by the relative amount of oxygen contained in the molecule, heat being produced only when oxygen from outside the molecule oxidises the elemental carbon and hydrogen within the molecule. In the case of carbohydrates, there is enough oxygen present in the molecule to oxidise all the hydrogen present and therefore heat is produced only from the oxidation of the carbon. In the case of fat, however, there is relatively much less oxygen present and more carbon and hydrogen atoms requiring oxygen from outwith the molecule for oxidation during combustion (Maynard and Loosli, 1956).

2:3:5 Factors which affect the use of fat in milk substitute diets.

2:3:5:1 Quality of fat.

Although many fats of both animal and vegetable origin can be included in a milk substitute diet for calves, they do not all have the same digestibility. (Table 2:3)

Table 2:3

Digestibility of different fats by calves when they were included in milk and milk substitute diets

(After Raven, 1970)

Fat	Mean digestibility (%)
Butterfat	96
Lard	90
Tallow	87
Palm oil	89
Palm-kernel oil	89
Coconut oil	94

The digestibility of a particular fat can be attributed to the constituent fatty acids of that fat, and in particular to the chain length and degree of saturation of the constituent fatty acids. In general, the shorter the chain length and the greater the degree of unsaturation the higher is the digestibility of the fatty acid.

Table 2:4

Apparent digestibility of dietary fatty acids by Holstein calves aged from six to 24 days

(After Radostits and Bell, 1968)

Fatty Acid		Apparent digestibility (%)
Caprylic	(C_8)	100
Capric	(C_{10})	100
Lauric	(C_{12})	94
Myristic	(C_{14})	73
Palmitic	(C_{16})	42
Palmitoleic	(C_{16})	89
Stearic	(C_{18})	26
Oleic	(C_{18})	75
Linoleic	(C_{18})	79

Melting point of a fat is closely correlated with the chain length and degree of saturation of its constituent fatty acids and therefore is a useful indicator of a particular fat's digestibility. Tristearin, for example, with a melting point of approximately 72 degrees C is considered to be virtually indigestible (Kondrey, 1964).

Because the very short chain fatty acids (C_4 - C_{10}). which account for approximately 19% of butterfat (Garton, 1963) are very well absorbed, this may account for the higher digestibility of butterfat compared with tallow (Table 2:3). In tallow there is a high proportion of stearic acid and a virtual absence of short chain fatty acids. A figure of 25% by weight of stearic acid in the depot fat of cattle compared with ten per cent in butterfat has been reported (Greenstone, 1967).

2:3:5:2 Method of adding fat to a milk substitute diet

Fat can be added to a milk substitute diet in two ways; by homogenising the fat into liquid skim milk followed by spray-drying or by blending the fat into skim milk powder with the aid of an emulsifying agent. The first method usually results in a milk substitute of a higher quality because the mean fat globule size produced by this method is usually around three to four μm whereas the blended fat contains fat globules in the range of ten to 20 μm in diameter (Roy, Shillam, Thompson and Dawson, 1961). Alopecia and diarrhoea have been induced in calves by feeding a milk substitute containing added fat where the size of the fat globule was more than three to four μm in diameter (Bate, Espe and Cannon, 1946; Kastelic, Bentley and Phillips, 1950; Huff, Waugh and Wise, 1951). However, the older and larger calves can probably tolerate fat globules of a greater diameter than three to four μm without any deleterious effect (Roy et al., 1961). Roy (1970e) recommended that for the young calf and for calves of the smaller breeds, the fat globule size in a milk substitute should be smaller than the fat globule size in a milk substitute fed to larger calves. This means that for young calves and in particular young calves of the smaller breeds of cattle, the method of adding fat to a milk substitute diet should be by homogenising it into liquid skim milk followed by spray-drying.

2:3:5:3

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2:3:5:3 Age of animal.

In the work mentioned previously (Radostits and Bell, 1968), the apparent digestibility of ether extract, (in a milk substitute containing mixed animal and vegetable fat) along with the other constituent fractions of the proximate analysis, was determined on bulked two-day samples over a period of 18 days, thus giving nine periods. (Table 2:5)

Table 2:5

Apparent digestibility of ether extract by calves aged from six to 24 days

(After Radostits and Bell, 1968)

Period No.	Ether extract digestibility %
1	29
2	45
3	43
4	51
5	67
6	79
7	79
8	82
9	82

Although all digestibility coefficients increased with age, the most marked increase in digestibility with age was noted with the digestibility of ether extract. This increase in digestibility of fat with age has been reported by various other workers (Cunningham and Loosli, 1954; Raven and Robinson, 1964; Roy, 1964).

2:3:5:4 Amount of fat included in the milk substitute diet.

If the fatty acids linoleic and arachidonic, which the pre-ruminant calf is unable to synthesise (Lambert, Jacobson, Allen and Zaletal, 1954) are added to the diet sufficient energy can be obtained from milk carbohydrates for a live weight increase of up to 600g/day (Rojas, Schweigert and Rupel, 1948; Blaxter and Wood, 1953).

Calves can survive on a low level of fat in the milk if they have previously received colostrum (Converse, 1949; Cunningham and Loosli, 1954) but calves fed on a fat-free milk substitute diet developed leg weaknesses and muscular twitches within five weeks and died unless a source of fat was supplied (Cunningham and Loosli, 1954). This condition, presumably caused by a deficiency of the fat soluble

Vitamin E, or of essential fatty acids, could be cured by feeding a milk substitute containing four percent lard and prevented by feeding a milk substitute containing one to two percent lard. It has also been shown that the feeding of a fat-free milk substitute to calves retarded growth, caused dandruff, dull hair coat and partial alopecia (Lambert et al., 1954). This condition, presumably caused by a deficiency of the essential fatty acids Linoleic and Arachidonic could be prevented by feeding a milk substitute containing three percent butter oil and cured by feeding a milk substitute containing two percent hydrogenated soya bean oil plus lecethin. However, fat is a desirable ingredient of milk substitute diets for calves because increased dietary fat levels can increase nitrogen retention by calves.

From a review of the literature, Munro (1951) concluded that when growing animals, receiving a diet adequate in protein but suboptimal in energy, are given additional fat or carbohydrate, this energy increment brings about increased nitrogen retention. Fat is a source of highly concentrated energy and because of this the desirable level of inclusion of fat in the diet of young calves depends on the intended growth rate of the calf.

Before 1960, the majority of milk substitutes contained one percent fat in the dry matter and had a calorific value of about half that of whole milk. Since that time the desirability of more intensive and less expensive calf rearing systems linked with the existence of a world surplus of fats, has resulted in the production and use of milk substitutes containing up to 20% fat. Because the dry matter of whole milk contains approximately 26% fat it is likely that the rate of inclusion of fat in a milk substitute will rise to this level when more experience is gained in the techniques of incorporating fat into milk substitutes.

2:3:6 The effect of dietary fat level on nitrogen retention by the pre-ruminant calf.

A comparison has been made (Raven and Robinson, 1961) using 14-week old Ayrshire calves of two diets; one containing 25.7% crude protein and 2.5% ether extractable material and the other containing 24.3% crude protein and 24.0% ether extractable material. The diet containing the higher amount of fat led to a higher efficiency of nitrogen retention by the calves (42.1%) than the low fat diet (22.1%). This finding indicates that the lack of available dietary energy in the low fat diet was an important factor in limiting the retention of nitrogen. Similarly, in other work (Anon., 1967) six milk substitutes with fat levels ranging from 2.0 to 22.1% and with corresponding gross energy values ranging from 4.200 to 5.134 Mcal/kg dry matter were compared. The corresponding nitrogen retention (as percentages of intake) ranged from 17.6 to 48.7%. Also, with two iso-caloric diets (5.200 Mcal/kg dry matter), one containing butterfat and the other containing tallow, it was shown that the greater metabolisable energy supplied by butterfat resulted in a higher nitrogen retention by calves fed this diet (48.7% as opposed to 43.5%).

In more recent work (Roy, Stobo and Gaston, 1970) the conclusion that dietary fat was not a readily available source of energy for increasing muscle deposition appears to contradict any suggestion of a correlation between nitrogen retention and dietary energy supplied as fat. These conclusions were based on the fact that, in absolute terms, nitrogen retention by calves was similar on a skim milk and a milk substitute diet containing 20% added fat when these diets were fed <u>ad libitum</u>. However, it can be calculated that the nitrogen retention by calves fed the skim milk diet was 36.4% and by calves fed the diet containing 20% fat it was 43.9% of the nitrogen intake, indicating a more efficient use of nitrogen by calves fed the high fat diet.

In other investigations (Roy, Stobo, Gaston and Greatonex, 1970) three milk substitute diets were fed to calves aged four weeks. The diets were LFHP, HFHP and HFLP,

where LF = 20% fat (on a dry matter basis)
HF = 30% fat (on a dry matter basis)
HP = 26-29% crude protein (on a dry matter basis)
LP = 19% protein (on a dry matter basis)

In absolute terms there was no difference in nitrogen retention between the calves on the two high protein diets (LFHP and HFHP) and this led these workers to conclude that increasing the energy content of a milk substitute by increasing the fat content from 20 to 30% of the dry matter did not result in an increased nitrogen retention by the calves. However, if nitrogen retention had been expressed as a percentage of nitrogen intake the values for nitrogen retention by the calves on the LFHP, HFHP and HFLP diets would have been 50, 59 and 62% respectively, which corresponds to the biological values of milk protein of 64.8, 74.2 and 81.8%. The biological value of 81.8% for the milk protein in the HFLP diet probably indicates that protein was the limiting factor for growth on this diet.

From the above investigations, it would appear that when nitrogen retention by calves is expressed in absolute terms it is not affected by the level of fat in the diet, but when nitrogen retention by calves is expressed as a percentage of nitrogen intake, the value for nitrogen retention increases as the fat content of the diet increases up to a level where fat comprises 30% of the milk substitute dry matter. In other words as the fat content of a milk substitute diet increases to 30% of the dry matter of the diet, there is a corresponding increase in the efficiency of nitrogen utilization by the calf. It is not clear, however, whether this increase in the efficiency of nitrogen retention resulted from increasing the fat content of the diet or from decreasing the protein content of the diet.

2:3: 7 The effect of dietary fat level on water retention and fat deposition by the pre-ruminant calf.

There is general agreement that the inclusion of fat in a milk substitute diet for calves increases the dry matter content of the faeces and therefore reduces the likelihood of diarrhoea. This may be because either the fat itself is costive (Ash, 1964) or as has been shown in infants (Weijers and van de Kamer, 1965) and suggested as occurring in the calf (Roy, 1969) that a reduction in the levels of protein and soluble carbohydrates in the diet by the inclusion of high levels of fat reduces the likelihood of diarrhoea attributable to excessive ingestion of protein or carbohydrate.

The inclusion of fat in a milk substitute also results in the deposition of fat in the carcass of the calf (Roy, Stobo and Gaston, 1970) and this fat can serve as a source of energy at weaning when dietary intake of energy is low.

2:3:8 The metabolism of calcium, phosphorus and magnesium by the pre-ruminant calf.

2:3:8:1 Levels of calcium, phosphorus and magnesium in cows' milk.

The calcium content of cows' milk, which is approximately 1.2g/litre, is governed mainly by genetic factors and therefore remains relatively constant throughout the lactation (Golding, Mackintosh and

Mattick, 1935; Robinson, Hlynka, Herman and McArthur, 1947; Sharara, 1956). It cannot be altered by diet and therefore a deficiency or an excess of calcium in the diet will not influence the level of calcium in milk (Turner, Kane and Hale, 1932; Groenewald, 1935; Hansson, 1948). Where a deficiency in the diet is severe calcium is mobilised from the skeleton (Luick, Boda and Kleiber, 1957).

As with calcium, the phosphorus content of cows' milk is governed chiefly by genetic factors and remains relatively constant at approximately 1.0g/litre (Golding et al., 1935). The colostrum may contain more than 2.0g phosphorus/litre (Garrett and Overman, 1940), but this content drops to the normal level during the first month of lactation. Milk phosphorus is also unaffected by the cow's nutrition. Even extreme levels of phosphorus in the diet have no effect on the phosphorus concentration in milk (Becker, Eckles and Palmer, 1927; Turner, et al., 1932; Groenewald, 1935; Hansson, 1948). The phosphorus concentration in milk remains the same even when milk production varies and therefore the total excretion of phosphorus in milk is directly correlated with milk yield (Kleiber and Luick, 1956). From the above information, therefore, the calcium: phosphorus ratio in cows' milk remains relatively constant at 1.2:1 throughout the greater part of the lactation.

The magnesium content of cows' milk is approximately ten percent of the calcium content (Nickerson, 1960). At the beginning of the lactation the magnesium content which is doubled or trebled in the colostrum, falls within one to three days to normal concentrations (Garrett and Overman, 1940). Throughout the remainder of the lactation the magnesium concentration in milk remains constant (Kemp, Deijs, Hemkes and van Es, 1961). Also the dietary mineral intake by the cow has no effect on the magnesium content of the milk (Groenewald, 1935).

The membrane of milk fat globules has a relatively high content of calcium, phosphorus and magnesium (Hare, Schwartz and Weese, 1952; Herald, Brunner and Bass, 1957). This helps to explain why breeds of cattle which produce milk with a high butterfat content also have a high content of calcium, phosphorus and magnesium in their milk (Black and Voris, 1934; Ellenberger, Newlander and Jones, 1950).

2:3:8:2 Absorption of calcium, phosphorus and magnesium by the calf.

The absorption of calcium from milk by the young calf decreases with age, but during the first month of life it is at least 92% and may be as high as 98% of the total calcium in the milk (Blackwood, Morris and Wright, 1935; Hansard, Comar and Plumlee, 1954; Smith, 1957). The reasons for decline with age in calcium retention has been reviewed by Roy (1959). When dietary calcium is much in excess of requirements of the calf, the percentage absorbed is reduced (Duncan and Huffman, 1934; Gueguen and Mathieu, 1965). At a maintenance level of milk intake, the percentage of calcium retained is 73% but has been shown to increase to 92% when the amount of milk fed is sufficient to give a live weight gain of 0.90kg/d (Blaxter and Wood, 1952). At a maintenance level of food intake 73% of the calcium consumed was retained. This corresponded to an absolute value of 3.13g calcium retained per day. At the same time 2.83g of nitrogen and 1.64g of phosphorus were retained each day. The authors calculated that the total body weight gain as a result of these retentions was about 90g/day and that this gain was presumably balanced by a loss of body fat and by slight dehydration of the tissues.

The absorption of phosphorus from milk by young calves is between 94 and 99% of the total phosphorus in the milk (Blackwood _et al._, 1935; Blaxter and Wood, 1952) provided that the intake of phosphorus is not excessive, in which case the value may be as low as 82%. The absorption of magnesium is between 75 and 90% at one month of age (Smith, 1957) but falls to about 40% at 21-34 weeks (Smith, 1959). There is also a decrease in percentage magnesium retained as the magnesium content of the diet is increased above requirements (Raven and Robinson, 1958).

Excretion of calcium is mainly in the faeces, urinary excretion, being always very low. With phosphorus, excretion is mainly in the urine, faecal excretion being small by comparison. The total amount of magnesium excreted is normally fairly constant, but a high faecal excretion is usually accompanied by a low urinary excretion, and _vice versa_ (Raven and Robinson, 1959).

2:3:8:3 Relation between nitrogen retention and calcium, phosphorus and magnesium retention.

The retention of calcium, phosphorus and magnesium has been shown to be a function of general growth and the retention of these minerals is related to the retention of nitrogen (Owen, 1952).

About 99% of the calcium of the body is present in the bones and teeth, whereas nitrogen although present in the bone, is found mainly in the organs and soft tissues of the body. A significant correlation coefficient of +0.743 was, however, found (Raven and Robinson, 1960) between the weights of nitrogen and calcium retained by calves from each of a series of milk substitutes. In the same work, the correlations between the retentions of nitrogen and phosphorus (+0.709) and between the retentions of nitrogen and magnesium (+0.778) were also significant. It is not surprising that in this work close correlations were also obtained between the retentions of calcium, phosphorus and magnesium. The correlation between the retentions of calcium and phosphorus, calcium and magnesium and phosphorus and magnesium were +0.679, +0.792 and +0.789 respectively.

It has been reported that calcium and phosphorus retention values can, in fact, be estimated if nitrogen retention is known by using factors obtained by Mitchell and McClure (1937) in which phosphorus retention = 27% of nitrogen retention, and calcium retention = phosphorus retention x 1.71.

2:3:8:4 Influence of dietary fat on calcium, phosphorus and magnesium retention in pre-ruminant calves.

Since the retention of calcium, phosphorus and magnesium is closely related to the retention of nitrogen which, in turn, as has already been shown, is related to the level of dietary energy in a milk substitute diet, it follows that the retention of these minerals could be, albeit, indirectly, influenced by the percentage of inclusion of fat in a milk substitute diet. In work mentioned already (Anon., 1967) where nitrogen retention increased when the gross energy intake increased from 4.200 to 5.134 Mcal/kg dry matter, the retentions of calcium, phosphorus and magnesium also increased corresponding to the increase in gross energy intake.

The inclusion of fat in a milk substitute diet can also have a direct effect on the metabolism of these minerals. For example, the loss of calcium in the faeces as calcium soaps in conditions of abnormal fat digestion has been mentioned (Owen, 1952) and in more recent work (Raven and Robinson, 1958) undigested fat was hydrolysed in the alimentary tract and the resultant increase in output of fatty acids was related to increased excretions of calcium and magnesium. Under such conditions, the retention of phosphorus appears to be influenced largely by the degree of calcium retention (Raven and Robinson, 1959).

More recently (Ternouth, Roy, Stobo, Ganderton, Gillies and Shotton, 1974), a regression has been calculated between intestinal absorption of calcium and the digestibility of fat in milk substitute diets fed to calves. As calcium absorption increased from 12 to 96% and fat digestibility increased from 40 to 95% the regression calculated was $y = 0.308 + 0.538x$

where y = digestibility of fat,

and x = absorption of calcium.

It was deduced from this equation that when absorption of calcium was zero only 30.8% of the fat was digested. In this work this value was similar to the proportion of fatty acids with less than 16 carbon atoms plus the polyunsaturated fats in the diet (29%) all of which were known to have a high digestibility in the calf.

Retentions of nitrogen, calcium and phosphorus of 25.07, 9.08 and 5.29g/d respectively by milk-fed calves have been reported (Blaxter and Wood, 1952).

Other workers (Raven and Robinson, 1959) using a spray-dried whole milk powder into which had been homogenised about ten percent (on a dry matter basis) of additional butterfat obtained nitrogen calcium and phosphorus retentions of 15.7, 5.43 and 3.20g/d respectively. The latter workers concluded that the low nitrogen retention value did not result from a deficiency of dietary energy, but from inadequate supplies of calcium and phosphorus in the diet. Thus, with milk substitute diets containing fat levels as high as that used by these workers, it may be necessary to provide greater amounts of calcium and phosphorus in the diet. Also the increase in digestibility of fats of low digestibility appears to be associated with a reduction in the faecal excretion of neutral fat and an increase in the faecal excretion of saponified fat (Thomke, 1963 a and b). Using a fat of low digestibility therefore may increase the requirement of calcium and magnesium due to the formation and subsequent excretion of soaps of these minerals.

2:4 Calf rearing systems

2:4:1 In developed countries.

There are basically only two methods of rearing calves. The "natural" method where the calf is allowed to suck from its dam or a nurse cow, and the "artificial" method where whole milk or a milk substitute is fed to the calf by any method other than the "natural" method. There are variations of both systems in the quantity of milk that the calf is allowed to consume daily, and the age of the calf at weaning. These variations are mainly dependant upon the future use of the calf. Calves which will be used as replacements in a dairy here are normally artificially reared on restricted quantities of milk or milk substitute and weaned early; whereas calves from herds used for beef production are normally suckled and weaned at the end of the dams' lactations.

Nine methods of rearing calves have been suggested as being suitable for use in developed countries (Roy, 1970f).

(i) Veal production - slaughter at 12-13 weeks.

(ii) Single suckling - weaning at 6-24 weeks.

(iii) /

(iii) Multiple suckling - weaning at 6-16 weeks.

(iv) Restricted whole milk or milk substitute and limited skim milk or buttermilk - weaning at 8-24 weeks.

(v) Restricted whole milk or milk substitute and limited whey - weaning at 8-24 weeks.

(vi) Restricted whole milk or milk substitute and concentrate mixture - weaning at 8 weeks.

(vii) Restricted whole milk or milk substitute and concentrate mixture - weaning at 3-5 weeks.

(viii) Restricted whole milk and concentrates in gruel form - weaning at 12 weeks.

(ix) Restricted whole milk or milk substitute and grass - weaning at 8 weeks.

Method (i) is the most intensive form of calf rearing and is only of value where a demand exists for the type of meat produced and a ready supply of milk substitute is available.

Method (ii), probably the least sophisticated of the above systems, is practised in areas where herds used for beef production are maintained on poor quality pasture. In this system the growth rate of the calf is normally limited by the milk production of its dam.

In herds used for milk production where lactation yields are high, the third method is often used, but is now becoming less popular following the introduction of "nipple-feeders".

Methods (iv) and (v) are now seldom used in developed countries and previously were used only as a means of absorbing by-products from the milk processing industry.

Methods (vi) and (vii) are those most commonly used in developed countries as methods of rearing calves on minimal quantities of milk or by-products from the milk processing industry.

Method (viii), while being very popular in the past as a means of rearing calves on minimal quantities of whole milk, is now seldom used in developed countries and has been replaced by methods (vi) and (vii).

The major pre-requisite of Method (ix) is a high standard of grassland management, but even if high quality grass is available, the growth rate of the calf and in particular of the smaller calves, is restricted by the amount of grass that can be ingested.

In developed countries, therefore, calves are normally reared artificially and the "natural" system of rearing (method (ii)) is restricted to those areas with poor pastures or where beef production is the main objective.

2:4:2 In developing countries.

Most calves in developing countries are reared by "natural" methods, artificial rearing being restricted, by and large, to herds of *Bos taurus* and crossbred *Bos taurus*X*Bos indicus* animals used for milk production. There are at least six methods of rearing calves in developing countries.

(i) Milking twice daily with "calf at foot". By this method the calf is suckled by its dam for several minutes prior to morning and afternoon milkings, and is separated from its dam for the remainder of the day.

(ii) The calf is suckled by its dam for about one hour immediately after morning and afternoon milking, and then is separated from its dam for the remainder of the day.

(iii) "Once-a-day milking" or the "semi-range" system. In this method the cow is milked in the morning and the calf is allowed to run with it for the remainder of the day, and is separated from it at night.

(iv) Hand milking of half the udder twice daily and allowing the calf, at the same time, to suck from the other two quarters.

(v) Single suckling. By this method the calf obtains all the milk produced by its dam.

(vi) Artificial rearing. This is practised in only a few areas and normally only with Bos taurus calves.

In methods (i) - (v) weaning normally takes place when the milk production of the dam ceases. In method (vi) weaning normally takes place between 8-12 weeks of age.

The most recently recommended system of calf rearing suited to conditions in developing countries is based on method (ii) above (Preston and Ugarte, 1974). It consists of allowing the calf to suck from its dam for a limited period (30 minutes) twice a day immediately following machine or hand milking. Weaning takes place at 70 days. Calf growth rate on this system using Holstein calves can be 0.950kg daily. This system also has the advantages that it has been shown to increase total milk production of the dam by 60% and reduce the incidence of mastitis, compared with control cows which were milked by machine. When crossbred Holstein X Brahman cows were managed using this system, premature ending of lactation was also prevented. No data are yet available on the growth performance of pure Bos indicus calves reared by this method.

2:4:3 Customs relating to animal production in developing countries.

Very few owners of cattle in developing countries consider their stock as a means to an end, and prefer to think of them as an end in themselves. Cattle are, in many cases, a status symbol, a form of social capital and an integral part of religion. They are often prized more for their quantity rather than their quality and instead of being exploited commercially are kept for their intrinsic social value or for work. As livestock numbers increase through improved disease prevention techniques, there is the danger that much of the land used at present for livestock enterprises will become overstocked. In order to maintain their social standing in the community, it is inevitable that owners of cattle in developing countries will tend to increase their stock numbers in an attempt to compensate for high mortality rates. The situation is thus aggravated and will not improve until more information is obtained on the requirements of cattle and in particular calves in a tropical environment so that more efficient use can be made of the limited resources available.

2:5 Calf mortality rates.

Reports on post-natal mortalities in calves have only limited value because of the number of management practices involved and, in general, reflect merely the success or otherwise of these practices. In the U.K. the most recent survey on the mortality rate in young calves was carried out in 1962-63 (Leech, Macrae and Menzies, 1968). Of a total of more than two million calves, all of which had been reared on the same farms as they were born, the mortality rate was shown to be 5.0% to six months of age, and 5.7% to one year of age. In this survey the percentage mortality for a particular age of calf could be described by the function Log W + 1.72 where W is equal to the age of the calf (in weeks). Calf mortality rate in the U.K. during the first month of life has been estimated as approximately 75%, (Lovell and Hill, 1940), 64% (Leech <u>et al</u>., 1968), and 60% (Roy, 1974), of the total calf mortality to six months of age. About half of the mortality rate in calves in the above survey was shown to be as a result of enteric infections caused by the bacterium Escherichia coli.

Calf mortality rates quoted in developing countries tend to be misleading, because most of these values have been calculated from data obtained on government farms or livestock breeding stations where the standard of management of cattle and calves is likely to be superior to that normally practised by cattle owners in developing countries. An example of this difference can be quoted from the results of a survey in Cuba. Mortality rate, of Holstein calves at one institute in that country, was approximately eight per cent, but in a survey carried out at the same time of six farms in Cuba with a total of 2,000 cows, the average calf mortality rate was 25%, and on one farm it was 50% (Preston and Willis, 1970b). In many developing countries heifer calves receive relatively more attention than bull calves because of their future use as cows. In Western Uganda losses of heifer calves was 21.7% and for bull calves it was 46.7% (Wilson, 1963).

In the Serere herd of shorthorned Zebu cattle in Uganda, the calf mortality rate to weaning at nine months was 18% during the period 1940-49. Of the total number of calf deaths, approximately 50% could be attributed to East Coast Fever, and about 23% to "unknown causes" (Williams and Bunge, 1952). In the same herd between 1950 and 1954 the calf mortality fell to 13.9% and, because of improved veterinary techniques, of the total number of calf deaths only 14% could be attributed to East Coast Fever, but 61% of the deaths were attributed to "unknown causes" (Wilson, 1957). These "unknown causes" referred to calves which grew weak and died through failure to adapt to the system of bucket feeding. The calf mortality in the latter work at Serere was classified into monthly age groups and it was noted that there were three periods of high calf mortality.

<u>Period 1</u>: During the first month of life where death was due to a variety of causes, but most commonly to premature births, genetic defects and failure to feed.

<u>Period 2</u>: Between three and six months of age where death could be attributed to East Coast Fever.

<u>Period 3</u>: Around the time of weaning at nine months of age. All animals suffered from a "post-weaning check" and a few died.

2:6 Factors which affect the success of calf rearing systems

2:6:1 Milk let-down by *Bos indicus* cows.

In Uganda (Stobbs, 1967) indigenous *Bos indicus* cattle were managed under different systems, namely hand milking with bucket feeding of calves, milking half the udder and allowing the calf to suck from the other two quarters, and natural suckling on open range. Calf mortality was 14.3, 11.1 and 7.7% respectively. The author ascribed the high losses when the cows were milked and calves bucket-fed to the calf receiving insufficient milk because of a poor release of milk by many cows in the absence of the calf.

A successful attempt to manage *Bos indicus* cattle so that they would release milk satisfactorily when milked by hand in the absence of the calf was reported in India as early as 1934 (Sayer, 1934). In this work an increase in milk production by Sahiwal cows of 47% was achieved by a system of handling the animals so that they became accustomed to man. The technique involved regular massage of the udder before calving and, after calving, cows were milked four times daily and heifers were milked on average seven or eight and up to a maximum of 15 times daily. Calves were separated from their dams at birth and then fed, from a bucket, on milk drawn from their dams. It is significant that in this work no difficulties were reported in training calves to drink milk from a bucket. This observation is supported by the fact that calf mortality rate was only 1.4% during the milk feeding period.

There is some evidence of low calf vigour in Bos indicus calves immediately after birth. This low calf vigour could either be a characteristic of the calf or result from a low milk production by the dam. The latter possibility can be discounted, however, following the work of Chagas, Riggs, Smith and Cooper (1966) who reported that with Hereford and Brahman calves the latter lacked vigour despite the fact that milk production by Brahman cows exceeded Hereford cows by 32%, and that Brahman calves were heavier than Hereford calves at birth. In this work, calf losses to 205 days of age were significantly higher for Brahmans (23.5%) than for Herefords (4.3%). The temperament of Brahman cows has been reported to result in some calves failing to suck from their dams (De Rouen, Reynolds, and Meyerhoeffer, 1967) and in other work six percent of Red Sindhi cows refused to suckle their calves from birth (De Rouen, Reynolds and High, 1963).

2:6:2 Requirement of the young calf for milk.

A calf growth rate of one percent per day during the first three months of life has been recommended (Roy, 1970a). To achieve this growth rate the quantities of whole milk that should be fed to calves during the first three months of life can be calculated from figures supplied by Roy (1970g). For calves weighing 20kg and 30kg at birth, the total volume of milk required to produce a growth rate of approximately one per cent per day would be 360 litres and 510 litres respectively during the first three months post partum. These estimates are much greater than the 220 litres of milk which Wilson (1966) recommended feeding to <u>Bos indicus</u> calves during the first three months of life. With "once-a-day milking" it has been estimated (Parsons, 1958; Stobbs, 1967) that the milker obtains about 55% of the total milk yield and the calf about 45%. With cows producing 650 litres of milk in a lactation this would result in calves consuming only 290 litres of milk over an entire lactation. Webster and Wilson (1966b) considered this system to be wasteful of milk with cows producing more than 650 litres because they believed that the calf would obtain more milk than it required. The requirement by the young calf for milk based on the figures of Roy (1970g), suggest that Wilson (1966) and Webster and Wilson (1966) have underestimated the requirements of the young Bos indicus calf. This point is of particular importance because if too little milk is consumed by the calf during the first three to four months of life, not only will calf growth rate be slow, but also the calf will be weak when exposed, for the first time, to tick and fly-borne diseases and internal parasites.

2:6:3 The provision of supplementary food.

When Bos indicus calves are fed on only a part of the milk production from the dam, and when the dam produces less than 700 litres, the calf will receive insufficient milk to maintain a growth rate of one percent daily. Supplementation of the diet of the dam, which results in an increase in her milk production, can improve the growth rate of the calf, but more benefit is obtained by supplementing the diet of the calf. In a series of experiments, it has been shown that calves "creep-fed" from eight to 32 weeks consumed a total of 429kg of concentrates and gained 45kg in live weight, but if the same quantity of concentrates was fed to the cow, the increase in live weight by the calf, during the same period, was only 27kg (Kullman, Furr and

Nelson, 1961). From this work, therefore, if calf growth rate is the only objective, supplementary concentrates will be utilised more efficiently by the calf than by the cow.

The response by a cow to supplementary feeding must, however, be dependant upon its original nutritional status. In particular, if the nutritional status of a cow is sufficient for that cow to realise its potential for milk production, supplementing its diet will have no effect on milk production, and therefore no effect on calf live weight increase, but may increase the live weight of the cow (Antony and Starling, 1968).

2:6:4 Time of weaning.

Prior to the 1950's, the standard weaning age for calves in developed countries was seven to ten weeks (Norton and Eaton, 1946). Canadian workers found that this could be reduced to four weeks (Whiting and Clark, 1955), while British investigations led to weaning at 21-24 days (Preston, 1956; Quale, 1958). Mochrie and Murley (1957) have shown that it is possible to rear calves successfully on dry milk solids after only eight days of feeding on a liquid diet.

Calves weaned at between three and six weeks of age almost always suffer from some setback in growth in the immediate post-weaning period, but in experiments where early and late weaning procedures have been compared, performance was the same in both groups to 14 weeks (Castle and Watson, 1959), 18 weeks (Randel, 1966) or to slaughter at about 12 months (Aitken, Preston, Whitelaw, Macdearmid and Charleson, 1963).

The major factor which contributes to the success of any early weaning system is the level of dry food intake by the young calf. In this respect the type of dry food presented to the calf is important, because although forage is the natural diet of the ruminant, calves given access to concentrates and hay show a marked preference for concentrates, consuming up to 90% of total dry matter intake in this form (Preston, 1960). With calves weaned at five weeks of age and given free access to concentrates and hay only eight to nine percent of the total dry matter intake was in the form of hay (Roy, 1964; Stobo, Roy and Gaston, 1967).

The daily intake of hay by early weaned calves has also been shown to decrease as the daily allowance of concentrates is increased (Stobo, Roy and Gaston, 1966). At the highest level of concentrate intake

(2.27kg/day) hay contributed only four percent of the total dry food intake. Also, total dry matter intake and energy intake have been shown to increase and to result in an increase of 50% in live weight gain when early weaned calves were changed from a ration of concentrates and hay to one of concentrates alone (Ottersby and Rust, 1965). Similarly, poorer growth rates were reported when calves were given access to hay and concentrates compared with concentrates alone (Noller and Dickson, 1953; Quinones and Preston, 1968).

If the ration fed to early weaned calves contains only concentrates and no hay, there may be excessive development of the rumen papillae and this may lead to the condition "rumen parakeratosis" (Roy, 1970h). In this condition there is an increase in the length and width of the papillae, followed by a clumping together of the papillae and an encrusting of the tips of the papillae with dark keratinised material. The prevention of this condition would appear to be the only reason for including hay in the ration of young calves.

2:6:5 The nutritional value of tropical pastures for young calves.

Too much reliance can be placed on the value of tropical pastures as a food for young calves. A ruminant calf weighing 40kg requires 25g of digestible protein daily for maintenance (Roy, 1970d). On average good quality tropical pastures contain about 5.0% digestible protein and therefore a calf weighing 40kg would have to ingest approximately 500 g of grass dry matter daily to maintain its live weight. For a growth rate of one percent daily, the requirement of a calf weighing 40kg for digestible protein is approximately 145g daily which corresponds to an intake of grass dry matter of 2,900g daily. The maximum appetite of a calf weighing 40kg for a dry diet is approximately 800g per day (Roy, 1970j) and therefore tropical pastures, at best, will only be sufficient for maintenance of the calf's live weight.

The low nutritive value of tropical pastures for early weaned calves means that the concentrate ration supplied to the calf must be of a high quality and must be readily palatable, otherwise the early weaned calf will need to ingest large quantities of poor quality grass or hay to satisfy its nutritional requirement. The intensive rearing of cattle on large quantities of concentrates under feedlot conditions in developing countries is becoming increasingly popular. The early weaning of calves which are destined to be reared in feedlots would result in these animals being accustomed to concentrate feeding at an earlier age than they would if they had been fed milk for an extended period, and therefore the adaptation to fattening under feedlot conditions would be much easier.

2:7 The effect of an early weaning system of calf rearing on dam fertility.

By using early weaning techniques, the low fertility associated with nursing cows may be improved. Using Dairy Shorthorn cattle, it was found that cows nursing calves required 1.8 services per conception compared with 1.5 services per conception for those cows milked daily; only 57% of nursing cows conceived at the first service, compared with 71% of those being milked (Weltbank and Cook, 1958). More recently, it has been shown conclusively that allowing calves to suck from Holstein dams increased the mean interval from calving to first oestrous by 50% compared with dams which were machine milked (Saiduddin, Riesen, Graves, Tyler and Casida, 1967).

Under ranching conditions in Kenya, it has been noted that on those ranches with cattle of a high fertility record, calves were weaned earlier than on those with less favourable breeding results (Meyn, 1970).

Similarly, in Rhodesia, conception rates in Africander and Hereford cattle have been shown to improve as a result of their calves being weaned at nine to ten weeks (early weaning) instead of six to seven months (control).

Table 2:6

Conception rate of Africander and Hereford cattle under range conditions

(After Christie and Worthington, 1961, as quoted by Rose, Christie and Conradie, 1963)

Age of Cattle	Conception rates - Africander	
	Early weaning	Control
Four-year-old first calf heifers	93.3	40.0
Three-year-old first calf heifers	90.0	12.5
Mature cows	100.0	55.0
	Conception rates - Hereford	
Heifers	100.0	34.0
Mature cows	93.0	58.0

While this improvement in dam fertility as a result of early weaning their calves might be of limited value for beef production (unless calf rearing units can be established), its use with dairy cattle under range conditions, could result in a considerable improvement in overall productivity, provided milk production does not cease when the calves are weaned.

2:8 <u>Summary</u>

This review has served to emphasise that most of the existing systems of calf rearing used with <u>Bos indicus</u> calves involve the calf receiving insufficient milk for it to have a growth rate of one per cent of live weight per day. This low intake of food may have long term effects because the period when the effect of under-nutrition is most marked appears to be during the first three months of the calf's life.

There are no data in the literature of the ability of the young <u>Bos indicus</u> calf to digest milk or a milk substitute nor have any comparative studies been carried out on the digestibility of milk diets by <u>Bos indicus</u> and <u>Bos taurus</u> calves in the same environment with the same level of management. It has been assumed generally that management techniques which have been found to be appropriate for the rearing of <u>Bos taurus</u> calves will also be suitable for the rearing of <u>Bos indicus</u> calves. This may be an erroneous assumption.

From the work described in this thesis, it is hoped that a greater appreciation is obtained of the problems associated with the rearing of Bos indicus calves and that the application of conclusions drawn from this work will assist in increasing the overall productivity of Bos taurus and Bos indicus herds by using the available resources more effectively.

3. MATERIALS AND METHODS

Introduction

A total of three experiments have been completed; the location of the first, using Bos taurus calves, was the Centre for Tropical Veterinary Medicine, University of Edinburgh, and of the second and third, using Bos taurus and Bos indicus calves, was the University of the West Indies, Trinidad. In all three experiments, the management of the calves and the composition of the milk substitute diets fed to these calves were similar.

3:1 Animals.

In the first experiment 16 Bos taurus (Friesian) bull calves were used. These were supplied by a livestock auction market in Central Scotland. In the second experiment a total of 15 Bos indicus and 36 Bos taurus bull calves were used. Twelve Bos indicus calves which survived experiment 2 were used in experiment 3. The Bos indicus calves were obtained from two separate farms, 13 crossbred Brahman X Sahiwal calves from one farm and two Brahman calves from another. The Bos taurus calves were Holsteins obtained from individual farmers of the Crown Lands Development Project, Walterfield, Trinidad. The original Holstein stock from which these calves were obtained had been imported into Trinidad from Canada in the mid-sixties.

3:2 Milk substitute diets.

Three milk substitute diets were used, all of which were supplied by Messrs. L.E. Pritchitt and Co. Ltd., Royston, Herts.

Table 3:1

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Table 3:1

Composition of milk substitute diets

(% of dry matter)

	Diet1 (low fat)	Diet 2 (medium fat)	Diet 3 (high fat)
Skim milk solids	90	80	70
Fat (63% beef tallow, 33% coconut oil, 4% soya bean lecethin)	10	20	30

To each of these milk substitute diets, the following minerals and vitamins were added.

Magnesium	250	mg/kg dry matter
Iron	90	mg/kg dry matter
Manganese	40	mg/kg dry matter
Copper	10	mg/kg dry matter
Zinc	12	mg/kg dry matter
Iodine	120	ug/kg dry matter
Cobalt	100	ug/kg dry matter
Vitamin A	30,000	i.u./kg dry matter
Vitamin D_3	2,500	i.u./kg dry matter
Vitamin E	20	mg/kg dry matter
Vitamin B_{12}	30	ug/kg dry matter
B.H.A. (butylated hydroxyanisole)	32	mg/kg dry matter

The proximate analysis of the three milk substitute diets are shown in Table 3:2.

Table 3:2

Mean proximate analysis of milk substitute diets (dry matter basis)

	Diet 1	Diet 2	Diet 3
Crude protein	33.4	29.2	25.9
Fat (fatty acids)	10.8	21.0	30.2
Ash	7.5	6.5	5.9
Nitrogen free extractives	48.3	43.3	38.0

The reconstitution rate of all three milk substitutes was one part of milk substitute to six parts of water. The dry matter content of the three milk substitutes was approximately 94% and therefore the reconstituted milk substitutes had a dry matter content of 13.5 - 14.0%.

3:3 Experimental procedure.

All calves were obtained between three and seven days after birth and allowed an adaptation period of approximately one week before the collection of faeces and urine samples began.

Experiment 1.

Sixteen Friesian calves were purchased and allocated to four treatment groups. These were

Treatment Group	Treatment	No. of calves allocated
1	HF/LI	4
2	HF/HI	4
3	LF/LI	4
4	LF/HI	4

HF = Diet 3

LF = Diet 1

LI = Intake of reconstituted milk substitute restricted to eight per cent of live weight daily.

HI = Intake of reconstituted milk substitute restricted to 12% of live weight daily up to and for the duration of the first collection period and 16% of live weight daily thereafter.

Calves were weighed on arrival and allocated to treatment groups in such a way that the total weight of animals in each group was similar. One balance period comprising two five-day collection periods was carried through on all animals following the period of adaptation. Concentrates and hay were offered ad libitum to all animals following the balance period and weaning took place when calves were eight weeks old.

Harnesses were fitted to animals on arrival and these animals were then placed in metabolism cages. Total faeces excreted daily was collected in a polythene bag attached to the harness. These collection bags were replaced daily and the quantity of faeces excreted daily was weighed, after which individual faecal samples were transferred to other polythene bags for storage in a deep freeze at -25°C.

Polythene chutes were placed under the metabolism cages so that urine excreted would pass through the weldmesh floor of the cage onto these polythene chutes and flow into a plastic bucket positioned beneath the chutes. The total urine excreted daily by each animal was recorded and a ten per cent aliquot stored in a Winchester bottle containing 25 ml acetic acid. At the end of each collection period, the urine aliquots from individual calves were mixed thoroughly and transferred to a polythene bag and stored at -25°C in a deep freeze.

Faecal and urine samples were removed and weighed immediately before the calves were fed each morning.

Experiment 2.

Twelve Bos indicus (Zebu) and 36 Bos taurus (Holstein) calves were purchased and allocated to six treatment groups.

Treatment Group	Treatment	No. of calves allocated	
		Zebus	Holsteins
1	LF/LI	2	6
2	MF/LI	2	6
3	HF/LI	2	6
4	LF/HI	2	6
5	MF/HI	2	6
6	HF/HI	2	6
	Total	12	36

LF = Diet 1

MF = Diet 2

HF = Diet 3

LI = Intake of reconstituted milk substitute restricted to 10% of birth weight daily.

HI = Intake of reconstituted milk substitute restricted to 15% of birth weight daily up to and for the duration of the first five-day collection period and 20% of birth weight daily thereafter.

The reason for the discrepancy between the levels of reconstituted milk substitute intake between the work carried out in Scotland and that in Trinidad was that a larger number of animals was used in Trinidad, and I felt that because of the work involved and the risk of error in changing the absolute amount of milk substitute offered each week, it was better to feed the calves in Trinidad according to their birth weights and maintain this absolute level of feeding throughout the period during which milk was fed to the calves. During the balance periods, the intake level of eight per cent of live weight calculated weekly which was used in Scotland was similar to a basic level of ten per cent of birth weight which was used in Trinidad.

With the high intake groups in all experiments, the reason for providing a lower level of intake up to and including the first collection period (12% in experiment 1 and 15% in experiments 2 and 3), was to avoid the possibility of overfeeding the very young calf which can result in diarrhoea (Roy, 1970k).

One balance period comprising three five-day collection periods was carried through on each of the calves following the period of adaptation. This enabled the performance of Holstein calves to be compared with Zebu calves at the same age.

Because the supply of Zebu calves was limited and unpredictable, and as there was a ready supply of Holstein calves, the method of allocating calves to the experiment was that for each Zebu calf obtained a Holstein calf was also obtained, and both were allocated at random to the same treatment. Twelve Zebu calves and twelve Holstein calves were allocated in this way. A further 24 Holstein calves were obtained in four groups of six animals, and the animals in each group were allocated at random to the six treatments.

Experiment 3.

A further 15-day balance period comprising three five-day collection periods was carried through on the twelve Zebu calves used in experiment 2, when these calves reached the same live weight as the Holstein calves at birth. For this it was assumed that the average birth weight of Holstein calves was approximately 35kg. At the end of experiment 2, the quantity of reconstituted milk substitute offered to Zebu calves was increased to that quantity appropriate to a calf weighing 35kg and a second balance period was carried through when individual Zebu calves reached this live weight. This enabled the performance of Holstein calves to be compared with Zebu calves at the same live weight.

In experiment 3, the experimental layout was of a balanced crossover design, so that for a particular level of reconstituted milk substitute intake (either low or high) each Zebu calf was fed, for the duration of one collection period each of the three milk substitute diets. The Zebus were numbered one to 12 and were allocated to the second balance period as follows:

	Collection period		
Treatment	1	2	3
LF/LI	1 and 6	2 and 3	4 and 5
MF/LI	3 and 5	1 and 4	2 and 6
HF/LI	2 and 4	5 and 6	1 and 3
LF/HI	7 and 12	8 and 9	10 and 11
MF/HI	9 and 11	7 and 10	8 and 12
HF/HI	8 and 10	11 and 12	7 and 9

No harnesses were used for the collection of faeces from calves in experiments 2 and 3. Faeces were scraped from the floor of the individual metabolism cages as soon as possible after excretion. Urine was collected and composite samples stored as in experiment 1. Faeces samples were stored in air-tight plastic containers at -25°C.

Concentrates and freshly cut grass were offered daily to Holstein calves immediately after the third collection period in experiment 2, and these calves were weaned at eight weeks of age. Concentrates and freshly cut grass were offered daily to Zebu calves immediately after the third collection period of experiment 3 and these calves were weaned three weeks after concentrates and grass were first offered to them.

3:4 Chemical Analysis of samples.

Experiment 1.

Faecal samples were bulked in each of the collection periods. For each balance period, therefore, there were two composite faecal samples corresponding to the two collection periods for each animal. Urine samples from individual animals were also bulked together in each of the collection periods.

Experiments 2 and 3.

Faecal samples were bulked as in experiment 1 to provide three composite faecal samples corresponding to each of the three collection periods for each animal. Urine samples were treated as in experiment 1.

Faecal samples.

Experiment 1.

Approximately 60g of wet faeces were weighed accurately into a previously weighed dry tin foil dish. From this approximately 5g were transferred to a 300ml Kjeldahl flask for nitrogen determination. The tin foil dish plus remaining faeces was again weighed to determine accurately the weight of fresh faeces removed for nitrogen determination. A further 5g of fresh faeces was then removed from the tin foil dish and transferred to a 250ml Erlenmeyer flask for fat determination. The tin foil dish containing the remaining faeces was then reweighed to determine accurately the weight of fresh faeces used for fat determination. The difference between the original weight of the empty tin foil dish and its weight containing faeces after the removal of faeces for nitrogen and fat determinations gave the weight of fresh faeces on which the dry matter content was determined.

Experiments 2 and 3.

In these experiments faecal samples were partially dried in an oven at $60^{o}C$ for 48 hours then milled to a fine powder in an electric coffee grinder before being analysed.

Dry matter determination.

The dry matter content of all samples was determined by drying them in a forced draught oven at $100^{o}C$ for 48 hours.

Nitrogen determination.

To the 300ml Kjeldahl flask containing approximately 5g of fresh faeces was added 25ml of conc. sulphuric acid and two Kjeldahl catalyst tablets (each tablet contained 1g of Na_2SO_4 and 0.1g of $CuSO_4$ $5H_2O$.). This solution was then digested until colourless and then for a further 30 minutes. After cooling this solution was transferred with repeated washing to a 100ml volumetric flask, again allowed to cool and made up to the mark with distilled water. After shaking, five ml of this digest was transferred to the inner compartment of a Markham Still and made alkali with Kjeldahl caustic soda (40% NaOH). At the outlet of the condenser unit of the Markham Still was placed 5 ml of $\frac{N}{5}$ H_2SO_4 in a 250 ml beaker as an acid trap. Distillation was allowed to continue for approximately 20 minutes after which the acid trap was removed, the end of the condenser unit was washed into this acid trap with distilled water. This solution was then titrated with $\frac{N}{25}$ NaOH to determine the volume of $\frac{N}{5}$ H_2SO_4 in excess of that required to neutralise the ammonia released from the original 5ml of faecal digest. From this the nitrogen content of the original sample of faeces could be calculated. The percentage crude protein of the faecal samples were obtained by multiplying the percentage nitrogen in the samples by 6.38.

Fat determination.

To the sample of fresh faeces in the 250ml Erlenmeyer flask was added 95ml of three per cent alcoholic potassium hydroxide containing 0.4% amyl alcohol. This solution was boiled on a steam bath for 30 minutes to saponify the fats present and then allowed to cool. To this was added 30ml of 33% (v/v) hydrochloric acid to liberate the fatty acids present. Fifty ml of petroleum spirit (40-60 B.P.) were then added and the mixture shaken vigorously for one minute. After allowing the mixture to settle, 20ml of the petroleum spirit extract was removed using a pipette and titrated with 0.1N alcoholic sodium hydroxide using phenolphthalein as indicator. On the assumption that one ml of 0.1N NaOH is equivalent to 0.0284g fatty acid, the fatty acid content of the original sample of faeces was calculated from the following equation.

$$\text{Percentage fatty acid in fresh faeces} = \text{Vol. 0.1N NaOH used} \times 0.0284 \times \frac{50}{20} \times \frac{100}{\text{Weight of fresh faeces used for fat determination.}}$$

$$= \frac{7.1V}{W}$$

where V = volume of 0.1N NaOH required in titration

and W = weight of fresh faeces used for fat determination.

This calculation assumes that the mean molecular weight of fatty acids present was 284 which is the molecular weight of stearic acid.

This method of determining the fatty acid content of samples was used in preference to other methods for estimating the ether extractable material in faeces because faecal excretion of unsaponifiable and neutral fat by young calves has been shown to be small irrespective of diet fed (Raven and Robinson, 1958) and by using this method the fatty acid content of faecal samples can be determined much quicker. The fatty acid content of up to 60 faecal samples per day can be determined by this method.

Ash determination.

The ash content of faeces samples was determined on the material used in the dry matter determination. Approximately two grammes of this material was weighed accurately into a previously weighed dry crucible, placed in a muffle furnace at 550°C and left overnight. The crucible was then transferred to a desiccator, allowed to cool to room temperature and reweighed. The difference between this final weight of crucible and ash and the original weight of the empty crucible gives the weight of ash resulting from the weight of dry matter taken. From this the ash content of dry matter can be calculated.

Determination of organic matter content.

The percentage organic matter in faecal dry matter was obtained by subtracting the percentage ash in faecal dry matter from 100.

Determination of nitrogen free extractives content.

The percentage nitrogen free extractives was obtained from the following equation.

NFE (%) in faecal dry matter = 100 − [%age ash in faecal dry matter + % fatty acid in faecal dry matter + % crude protein in faecal dry matter]

Determination of mineral content in faecal ash.

To the crucible containing faecal ash was added five ml of conc. HCl and the contents evaporated to dryness on a steam bath. A further five ml of conc. HCl was then added and the ash solution transferred to 100 ml volumetric flask and made up to the mark with distilled water.

The sodium and potassium content in faecal ash was determined by emission on a Pye Unicam SP90A Atomic Absorption Spectrophotometer. The calcium and magnesium content in faecal ash was determined by absorption on the same spectrophotometer. Lanthanum chloride was added to the sample for calcium determination to avoid calcium suppression in the presence of phosphate ions.

The phosphorus content of the faecal ash was determined by the method of Gomorri (1942). Five ml of ash solution was made up to 25ml with distilled water. To 0.5ml of this solution was added 4.5ml of 10%T.C.A., followed by one ml of ammonium molybdate solution and one ml of metol solution. The solution was then allowed to stand for 30 minutes and read at 680 millimicrons on a SP600 spectrophotometer against a standard phosphorus solution.

Gross energy determinations.

Gross energy values were only determined on the faecal samples obtained in experiments 2 and 3. These determinations were carried out using an adiabatic bomb calorimeter with benzoic acid as the chemocaloric standard. In experiment 1, the gross energy content of food and faecal samples were calculated by using the formula of Maynard and Loosli (1956) where gross energy content of sample (kcal)

= (crude protein content in g x 5.65)

+ (carbohydrate content in g x 4.15)

+ (fat content in g x 9.10)

Urine samples.

Dry matter determination.

The dry matter content of all urine samples was determined by drying 25ml of each sample in a forced draught oven at 100^{o}C for 24 hours.

Nitrogen determination.

Twenty five ml of urine were transferred to a 300ml Kjeldahl flask and the nitrogen content determined in the same manner as for faecal samples.

Determination of mineral content.

This was carried out as for the HCl faecal ash extract.

Gross energy determination.

The gross energy content of urine samples was estimated by assuming that 1g of urinary nitrogen had a gross energy value of 5.4 kcal (McDonald, Edwards and Greenhalgh, 1966).

Chemical analysis of milk substitute diets.

In each of the three experiments the milk substitute diets were analysed at the same time and in a similar manner to the faecal samples.

3:5 Statistical analysis.

The experimental designs of all three experiments have already been described. For statistical analysis each experiment was considered separately. The raw data obtained from these experiments were in form of daily records of each of the variants measured on each animal and were transferred to punch cards. This raw data together with derived data were then subjected to an analysis of variance by computer and the variance ratios obtained tested for significance. In the results section of this thesis the levels of significance used are *, **, and ***, which denote $P<0.05$, $P<0.01$ and $P<0.001$ respectively.

The raw data and the derived data which were subjected to an analysis of variance in each experiment were as follows:-

<u>Raw data</u> | <u>Derived data</u>

Live weight gain

Dry matter intake

Percentage dry matter in faeces

Excretion of dry matter in faeces

Excretion of dry matter in urine

Raw data contd.	Derived data contd.
	Total excretion of dry matter
	App. digestibility of dry matter
	Retention of dry matter
	Retention of dry matter as a percentage of dry matter intake
Nitrogen intake	
Excretion of nitrogen in faeces	
	Percentage nitrogen in faecal dry matter
	Crude protein intake
	Crude protein excreted in faeces
	App. digestibility of crude protein
Excretion of nitrogen in urine	
	Percentage nitrogen in urine dry matter
	Total nitrogen excretion
	Nitrogen retention
	Nitrogen retention as a percentage of nitrogen intake
	Nitrogen excreted in urine as a percentage of total nitrogen excreted
	Nitrogen excreted in urine as a percentage of nitrogen intake

Raw data contd.	Derived data contd.
Fat intake	
Fat excreted in faeces	
	Percentage fat in faecal dry matter
	App. digestibility of fat.
Ash intake	
Ash excreted in faeces	
	Percentage ash in faecal dry matter
	Percentage ash absorbed
	Organic matter intake
	Organic matter excreted in faeces
	App. digestibility of organic matter
	Nitrogen free extractives intake.
	Nitrogen free extractives excreted in faeces
	App. digestibility of nitrogen free extractives
Energy intake	
Energy excreted in faeces	
	App. digestibility of energy
	Energy excreted in urine
	Metabolisable energy
	Metabolisable energy as a percentage of energy intake

Raw data (contd.)	Derived data (contd.)
Water intake in milk	
Voluntary water intake	
	Total water intake
Urine excreted	
	Water balance
Heart rates	
Rectal temperatures	
Ca intake	
Ca excreted in faeces	
	Percentage Ca in faecal ash
Ca excreted in urine	
	Percentage Ca in urine dry matter
	Total Ca excreted
	Ca excreted in faeces as a percentage of total Ca excreted
	App. absorption of Ca
	Ca retention
	Ca retention as a percentage of Ca intake
Mg intake	
Mg excreted in faeces	
	Percentage Mg in faecal ash
Mg execreted in urine	

Raw data (contd.)	Derived data (contd.)
	Percentage Mg in urine dry matter
	Total Mg excreted
	Mg excreted in faeces as a percentage of total Mg excreted
	App. Mg absorption
	Mg retention
	Mg retention as a percentage of Mg intake
Na intake	
Na excreted in faeces	
	Percentage Na in faecal ash
Na excreted in urine	
	Percentage Na in urine dry matter
	Total Na excreted
	Na excreted in faeces as a percentage of total Na excreted
	App. absorption of Na
	Na retention
	Na retention as a percentage of Na intake
K intake	
K excreted in faecus	
	Percentage K in faecal ash

Raw data (contd.)	Derived data (contd.)
K excreted in urine	
	Percentage K in urine dry matter
	Total K excreted
	K excreted in faeces as a percentage of total K excreted
	App. absorption of K
	K retention
	K retention as a percentage of K intake
P intake	
P excreted in faeces	
	Percentage P in faecal ash
P excreted in urine	
	Percentage P in urine dry matter
	Total P excreted
	P excreted in faeces as a percentage of total P excreted
	App. absorption of P
	P retention
	P retention as a percentage of P intake.

4. RESULTS

4:1 Experiment 1

This experiment was carried out in Scotland using Friesian calves which were fed milk substitute diets containing 10% (L.F.) and 30% (H.F.) added fat at a low (L.l.) and high (H.l.) level of milk substitute intake during one balance period, which comprised two collection periods (CP1 and CP2) each of five days' duration.

Introduction

Of the four calves fed the HFL1 diet, two died before the start of the first collection period. The two remaining animals in this treatment group had to be removed from the experiment immediately after completing the second balance period because they were exhibiting symptoms of ill-health similar to the symptoms exhibited by those calves which died. Of the four calves fed the HFH1 diet, one died before the start of the first collection period, and a second died immediately after completing the second collection period. The remaining two calves in this treatment group were then also removed from the experiment as they, too, were exhibiting symptoms of ill-health similar to the symptoms exhibited by those animals which died.

These symptoms of ill-health included listlessness and poor appetite and eventually the animal became moribund with death following in 24 to 48 hours. Diarrhoea was not observed with these calves, but their faeces had a characteristic light-grey and pasty appearance.

Post mortem examination of the calves which died revealed extensive ulceration of and haemorrhages in the abomasal mucosa. The contents of the abomasum were light in colour and of a pasty consistency. Other organs appeared normal.

In the statistical analysis of this experiment values were estimated by the missing plot technique for one calf in the HFL1 treatment group so that for statistical analysis there were three calves in treatment groups HFL1 and HFH1 and four calves in treatment groups LFL1 and LFH1.

4:1:1 Digestibility of dry matter (Table 4:1:1)

The digestibility of dry matter was affected by the level of fat in the diet, the level of intake of the diet and the age of the calf. Calves fed the HF digested dry matter less efficiently than calves fed the LF diet (76.4% vs 91.6%); calves fed at the low level of intake of the diet had a lower apparent digestibility of dry matter than calves fed at the high level of intake of the diet (82.4% vs 87.3%) and the apparent digestibility of dry matter was lower in collection period 1 (CP1) than in collection period 2 (CP2) (81.4% vs 88.8%).

There was, therefore, an overall trend of increasing apparent digestibility of dry matter from 65.3% for calves fed the HFL1 diet during CP1 to 94.7% for calves fed the LFH1 diet during CP2.

Table 4:1:1

Influence of fat content in a milk substitute diet and level of milk substitute intake on the excretion and digestion of dry matter (DM) by Friesian calves during two consecutive 5-day collection periods, which corresponded to weeks 3 and 4 post partum

	Fat content of milk subst. dry matter				Level of milk Substitute intake				Collection Period			
	1 Low	2 High	3 SED	4 Sig	5 Low	6 High	SED	Sig	1	2	SED	Sig
DM intake (g/day)	550	533			434	651			521	564		
DM %age in faeces	17.2	17.1	3.3	NS	17.8	16.5	3.3	NS	17.0	17.2	1.8	NS
Excretion of DM in faeces (g/day)	44.1	121.0	14.3	***	75.0	79.1	14.1	NS	92.2	61.8	7.4	**
Excretion of DM in urine (g/day)	48.7	39.0	3.3	*	42.9	46.2	3.2	NS	45.8	43.3	2.8	NS
Total excretion of DM (g/day)	92.7	160.0	14.9	**	117.8	125.3	14.7	NS	138.0	105.1	8.9	*
App. digestibility of DM (%)	91.6	76.4	2.4	***	82.4	87.3	2.3	*	81.4	88.8	1.2	***

1 Milk substitute dry matter containing 10% added fat

2 Milk substitute dry matter containing 30% added fat

3 SED denotes standard error of the difference between means

4 NS denotes not significant, * denotes $P<0.05$, ** denotes $P<0.01$, *** denotes $P<0.001$

5 Intake of reconstituted milk substitute equivalent to 8% of calves live weight per day

6 Intake of reconstituted milk substitute equivalent to 12% of calves live weight per day during collection period 1 and 16% of calves live weight per day during collection period 2.

The excretion of dry matter in urine by calves fed the HF diet was significantly less than the excretion of dry matter in urine by calves fed the LF diet. Of the total dry matter excreted, 24.4% and 52.5% was excreted in urine by calves fed the high and low for diets respectively.

4:1:2 Live weight increase (Table 4:1:2)

Because live weight increases were measured over entire balance periods, live weight increases corresponding to individual collection periods are not available. The daily live weight increase was affected significantly by the level of milk substitute intake, but no significant difference could be shown between the mean live weight increases by calves fed the LF and HF diets.

4:1:3 Nitrogen metabolism (Table 4:1:3)

Nitrogen digestibility and retention were significantly affected by the fat content of the diet fed. More nitrogen was digested by calves fed the LF diet than by calves fed the HF diet, but significantly more

Table 4:1:2

Influence of fat content in a milk substitute diet and level of milk substitute intake on the daily live weight increase by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat content of milk substitute dry matter				Level of milk Substitute intake			
	1 Low	2 High	3 SED	4 Sig	5 Low	6 High	SED	Sig
Live weight increase (kg/day)	0.22	0.17	0.10	N.S.	0.05	0.34	0.10	**

1 to 6 See Table 4:1:1 for explanation

Table 4:1:3

The influence of fat content in a milk substitute diet and level of milk substitute intake on nitrogen metabolism by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat cont. of milk Sub. dry matter			Level of milk subst.intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
N. intake(g/day)	29.5	22.7		21.2	32.0		25.5	27.8	
N excretion in faeces (g/day)	3.3	6.6	**	4.8	4.7	NS	5.1	4.3	NS
N per cent in faecal DM	7.6	5.8	***	7.2	6.5	NS	6.3	7.4	*
App. digestibility of nitrogen (%)	88.2	69.5	***	75.8	84.5	*	78.0	82.3	*
N excretion in urine (g/day)	17.1	11.3	***	14.3	14.9	NS	13.9	15.3	NS
N percent in urine DM	35.2	30.4	NS	34.1	32.3	NS	30.9	35.5	NS
Total N excret.(g/day)	20.4	17.9	NS	19.1	19.6	NS	19.0	19.7	NS
N retention (g/day)	9.2	4.8	*	2.1	12.4	***	6.5	8.1	NS
N retention as %age N intake	29.0	16.5	*	8.6	38.7	***	21.4	25.9	NS

1 to 6 See Table 4:1:1 for explanation

nitrogen was excreted in urine by calves fed the LF diet than those fed the HF diet. With calves fed the LF diet 83.5% of the total nitrogen excretion was in urine while with calves fed the HF diet 63.1% of the total nitrogen excretion was in urine.

4:1:4 Digestion of fat (Table 4:1:4)

A significant difference was observed in apparent digestibility of fat between calves fed the LF diet (83.6%) and calves fed the HF diet (65.8%). The greater excretion of fat in the faeces of calves fed the HF diet resulted from not only a greater excretion of dry matter by these calves, but also because their faecal dry matter contained a higher proportion of fat compared with calves fed the LF diet.

The level of milk substitute intake did not appear to have affected the digestibility of dietary fat.

There was a significant increase in the apparent digestibility of fat with increasing age of calves (i.e. apparent digestibility of dietary fat was higher in CP2 than in CP1). The fat content of faecal dry matter was higher in CP2 than in CP1 but the effect of this was outweighed by less dry matter being excreted in CP2 than in CP1.

Table 4:1:4

The influence of fat content in a milk substitute diet and level of milk substitute intake on excretion and digestibility of fat by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat cont. of milk Sub. dry matter			Level of milk subst. intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
Fat intake (g/day)	51.1	155.4		76.4	115.2		92.1	99.5	
Fat excreted in faeces (g/day)	8.2	51.7	***	25.1	28.7	NS	29.0	24.7	NS
Fat percent in faecal DM	18.6	41.9	***	27.2	30.0	NS	25.8	31.5	***
App. fat digestibility (%)	83.6	65.8	*	73.2	78.7	NS	72.2	79.7	*

1 to 6 See Table 4:1:1 for explanation

4:1:5 Absorption of ash (Table 4:1:5)

Inspite of a lower intake of ash by those calves fed the HF diet the excretion of ash in the faeces by calves fed this diet was significantly greater than by those calves fed the LF diet. Consequently the apparent absorption of ash by calves fed the latter diet was significantly greater than by calves fed the HF diet (72.3% vs 7.2%).

Similar quantities of ash were excreted by calves fed at the two levels of milk substitute intake. Thus calves fed at the high level of milk substitute intake had a significantly higher apparent absorption of ash than calves fed at the low level of milk substitute intake.

There was a significant improvement in the apparent absorption of ash with age. This resulted from both a reduction in dry matter excretion with age and a reduction in the ash content of faceal dry matter with age.

4:1:6 Digestion of organic matter (Table 4:1:6)

The apparent digestibility of organic matter was lower for calves fed the HF diet compared with calves fed the LF diet. The level of milk substitute intake

Table 4:1:5

Influence of fat content in a milk substitute diet and level of milk substitute intake on excretion and absorption of dietary ash by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 & 4 post partum

	Fat cont.ofmilk Sub.dry matter			Level of milk subst. intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
Ash intake (g/day)	42.7	32.7		30.7	46.1		35.9	40.0	
Ash excreted in faeces (g/day)	11.0	28.2	***	19.2	17.5	NS	27.0	9.7	***
Ash percent in faecesDM	24.2	22.8	NS	25.1	22.1	NS	28.6	18.5	**
App. ash absorbed (%)	72.3	7.2	***	30.3	58.5	***	15.4	73.5	***

1 to 6 See Table 4:1:1 for explanation

Table 4:1:6

Influence of fat content in a milk substitute diet and level of milk substitute intake on excretion and digestibility of organic matter (OM) by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 & 4 post partum

	Fat cont.of milk Sub. dry matter			Level of milk subst. intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
OM intake (g/day)	507	500		403	605		484	524	
OM excreted in faeces (g/day)	33.1	92.7	**	55.8	61.5	NS	65.3	52.1	NS
App. OM digestibility (%)	93.2	80.9	***	86.1	89.8	NS	86.0	89.9	**

1 to 6 See Table 4:1:1 for explanation

did not appear to affect the digestibility of organic matter, but there was a significant increase in apparent digestibility of organic matter between periods.

4:1:7 Digestion of nitrogen free extractives (Table 4:1:7)

The nitrogen free extractives faction of the diets fed was digested well by all calves. However, the fact that negative values occurred in excretion rates of nitrogen free extractives suggests that the method of calculating absolute quantities of nitrogen free extractives was erroneous. This observation becomes clearer when the excretion rates of nitrogen free extractives by calves in individual treatment groups are considered (Table 4:1:7:1).

Table 4:1:7:1

Influence of fat content of a milk substitute diet and level of milk substitute intake on the excretion of nitrogen free extractives by Friesian calves during two consecutive 5-day collection periods (g/day)

	Low intake		High intake	
Collection period (CP)	1	2	1	2
LF diet	3.2	1.8	5.9	4.1
HF diet	2.2	-8.5	2.9	-1.8

Table 4:1:7

Influence of fat content in a milk substitute diet and level of milk substitute intake on digestion of nitrogen free extractives (NFE) by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 & 4 post partum

	Fat content of milk subst.dry matter				Level of milk Substitute intake				Collection Period			
	1 Low	2 High	3 SED	4 Sig	5 Low	6 High	SED	Sig	1	2	SED	Sig
NFE intake (g/day)	268	200			191	286			230	247		
NFE excreted in faeces (g/day)	3.8	-1.4	1.5	**	0.7	3.1	1.5	NS	3.7	-0.6	0.8	***
App. digestibility of NFE (%)	98.6	100.0	0.7	**	100.0	99.1	0.7	NS	98.4	100.0	0.3	***

1 to 6 See Table 4:1:1 for explanation

The negative values are restricted to those calves fed the high fat diet during CP2. This suggests that the fatty acid content of fat excreted by calves fed the high fat diet was different from those fed the low fat diet and that, in fact, the average molecular weight of the fatty acids excreted by calves fed the high fat diet was less than 284.

4:1:8 Energy metabolism (Table 4:1:8)

The energy digested by calves fed the HF diet and by calves fed the LF diet was similar, but the apparent digestibility of energy was lower for calves fed the HF diet than for calves fed the LF diet. Significantly less energy was lost in urine by calves fed the HF diet than by calves fed the LF diet. Intake of metabolisable energy by both groups of calves was similar, but metabolisable energy as a percentage of gross energy intake was significantly lower by calves fed the HF diet than by calves fed the LF diet.

Energy metabolism was also shown to be more efficient at the high level of milk substitute intake than at the low level of milk substitute intake, and to increase with age. (Table 4:1:8:1)

Table 4:1:8

Influence of fat content in a milk substitute diet and level of milk substitute intake on metabolism of energy by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat content of milk subst. dry matter				Level of milk substitute intake				Collection Period			
	1 Low	2 High	3 SED	4 Sig	5 Low	6 High	SED′	Sig	1	2	SED	Sig
Gross energy intake(kcal/day)	2635	3092			2262	3401			2719	2943		
Energy excreted in faeces(kcal/day)	214	731	106	***	418	453	105	NS	477	395	51	NS
App.digestibility of energy (%)	91.5	75.6	3.1	***	82.3	87.1	3.1	NS	82.4	87.0	1.3	**
Energy excreted in urine(kcal/day)	92	61	4.4	***	77	80	4.3	NS	75	83	5.0	NS
Metabolisable energy intake(kcal/day)	2329	2300	130	NS	1767	2868	129	***	2167	2465	29	***
Metabolisable energy as %age of gross energy intake	88.4	74.4	3.3	**	78.1	84.3	3.3	**	79.7	83.8	1.6	*

1 to 6 See Table 4:1:1 for explanation

Table 4:1:8:1

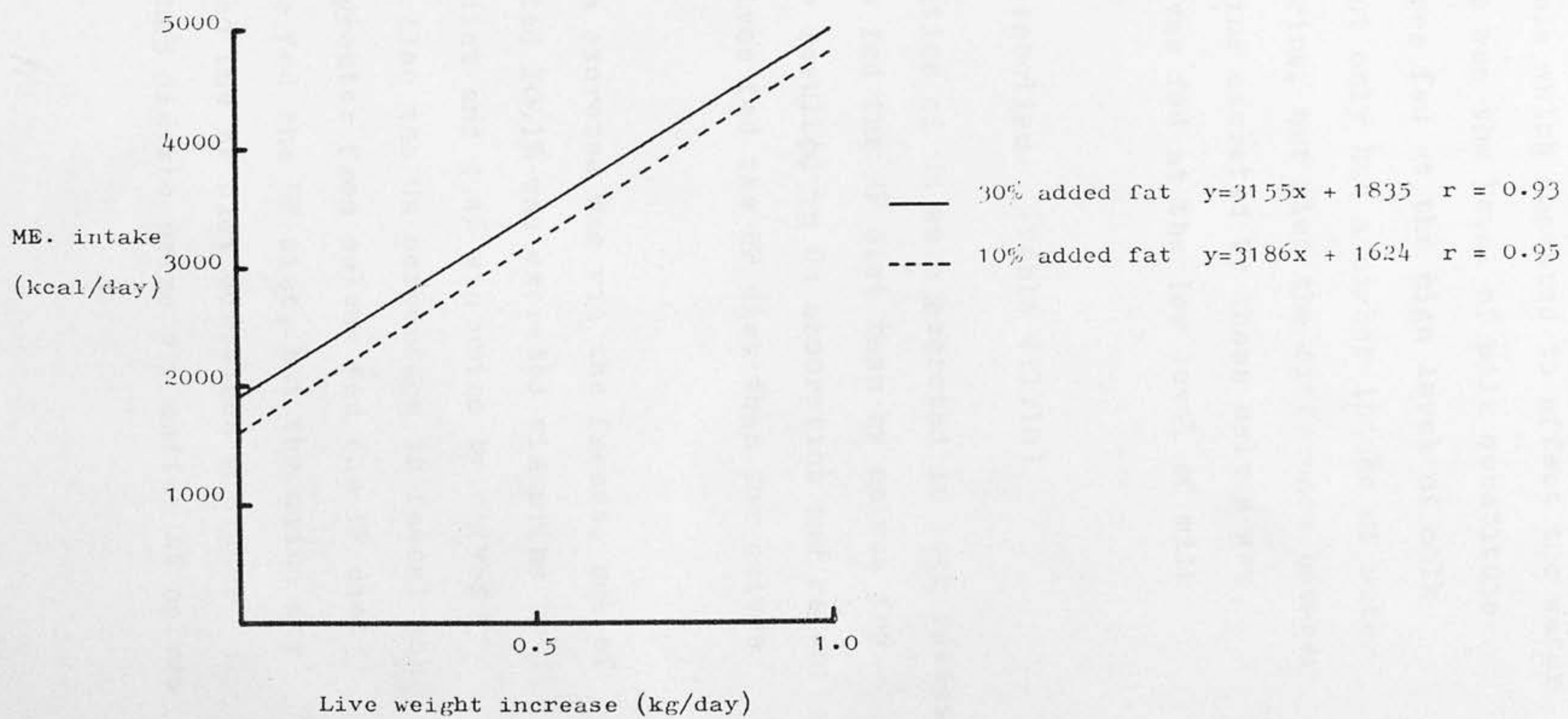
The influence of fat content of a milk substitute diet and level of milk substitute intake on metabolisable energy as a percentage of gross energy intake by Friesian calves during two consecutive 5-day collection periods (%)

	Low intake		High intake	
Collection period	1	2	1	2
LF diet	83.0	89.7	88.2	91.0
HF diet	66.1	70.7	76.5	79.9

In all treatment groups metabolisable energy represented 97% of the energy digested.

Regressions were calculated of the relationship between live weight increase and metabolisable energy intake for calves fed the low and high fat diets. (Fig 4:1:1) From these regressions it would appear that when live weight increase was zero the metabolisable energy intake by Friesian calves fed the low and high fat diets was 1624 and 1835 kcal/day respectively. On a unit live weight basis these values correspond to 43 and 46 kcal metabolisable energy (ME)/kg live weight/day, or 44.8 and 47 kcal digested energy DE/kg live weight/day. Also for one kilogramme live weight increase/day the metabolisable energy required by calves fed the LF and HF diets were 3186 and 3155 kcal/day respectively. These values are similar to those obtained by Blaxter and Wood (1951) using Ayrshire calves.

Fig. 4:1:1 Relationship between live weight increase and metabolisable energy intake by Friesian calves between 3 and 4 weeks of age when fed milk substitute diets containing 10% and 30% added fat during a 10-day balance period.



4:1:9 Water metabolism (Table 4:1:9)

The only variable which appeared to affect the water metabolism by calves was the level of milk substitute intake. Those calves fed at the high level of milk substitute intake not only had a higher intake of water and excreted more urine, but also the difference between water intake and urine excreted by these calves was greater than by calves fed at the low level of milk substitute intake.

4:1:10 Calcium metabolism (Table 4:1:10)

Greater quantities of Ca were excreted in both faeces and urine by calves fed the HF diet than by calves fed the LF diet. This resulted in Ca absorption and retention being lower for calves fed the HF diet than for calves fed the LF diet.

Most of the Ca excreted was via the faeces, but of the total Ca excreted 10.1% was excreted via urine by calves fed the HF diet and 4.4% via urine by calves fed the LF diet. Also the Ca percentage in faecal ash was significantly greater from calves fed the LF diet compared with those fed the HF diet, but the urine dry matter of calves fed the HF diet contained a higher percentage of Ca than did the urine dry matter of calves fed the LF diet.

Table 4:1:9

Influence of fat content in a milk substitute diet and level of milk substitute intake on water metabolism by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat content in milk subst. dry matter				Level of milk substitute intake				Collection Period			
	1 Low	2 High	3 SED	4 Sig	5 Low	6 High	SED	Sig	1	2	SED	Sig
Water intake in milk (kg/day)	3.5	3.3			2.8	4.1			3.3	3.6		
Urine excreted (kg/day)	3.1	2.8	0.2	NS	2.5	3.4	0.2	*	2.9	3.0	0.2	NS
Difference (kg/day)	0.4	0.5	0.1	NS	0.3	0.7	6.1	*	0.4	0.6	0.2	NS

1 to 6 See Table 4:1:1 for explanation

Table 4:1:10

Influence of fat content in a milk substitute diet and level of milk substitute intake on calcium metabolism by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat cont.in milk sub.dry matter			Level of milk sub. intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
Ca intake (mg/day)	6949	6084		5222	7934		6271	6885	
Ca excreted in faeces (mg/day)	2254	2763	NS	2349	2596	NS	2584	2361	NS
Ca percent in faeceal ash	23.7	13.4	***	18.1	20.5	NS	12.4	26.2	***
Ca excreted in urine (mg/day)	103	286	***	205	157	NS	186	177	NS
Ca percent in urine DM	0.20	0.73	***	0.50	0.36	*	0.39	0.47	NS
Total Ca excreted (mg/day)	2357	3049	NS	2554	2753	NS	2769	2534	NS
Ca excreted in faeces as %age tot.Ca excreted	95.6	89.9	**	92.3	94.1	NS	93.3	93.1	NS
App.absorp.of Ca (%)	66.5	52.8	*	54.3	66.9	NS	56.6	64.6	NS
Ca retention(mg/day)	4592	3034	**	2668	5180	***	3501	4347	**
Ca retention as %age of Ca intake	65.0	47.7	*	50.2	64.9	*	53.6	61.5	NS

1 to 6 See Table 4:1:1 for explanation

Significantly more Ca, in absolute terms, was retained by calves fed at the high level of intake than by calves fed at the low level of intake. Also the efficiency of retention of Ca by the former group of calves was superior to the latter group of calves.

In absolute terms there was an increase in retention of Ca with age, but this was probably due to a greater intake of Ca by calves in CP2 than in CP1 as the efficiency of retention of Ca was similar between collection periods.

Regressions were calculated of the relationship between the apparent absorption of Ca and the apparent digestibility of fat by calves fed the low and high fat diets (Fig 4:1:2). By extrapolation it can be seen that when Ca absorption is zero the apparent digestibility of fat by calves fed the LF and HF diets would be 48.8% and 22.6% respectively. Also, from these regressions, as the apparent digestibility of fat approaches 100% so the apparent absorption of Ca also approaches 100%.

4:1:11 Magnesium metabolism (Table 4:1:11)

About 52% of the Mg intake was retained by calves fed the LF diet, but only 36% of the Mg intake was retained by calves fed the HF diet. The lower efficiency

Fig. 4:1:2 Relationship between apparent absorption of calcium and apparent digestibility of fat by Friesian calves between 3 and 4 weeks of age when fed milk substitute diets containing 10 and 30% added fat during a 10-day balnce period.

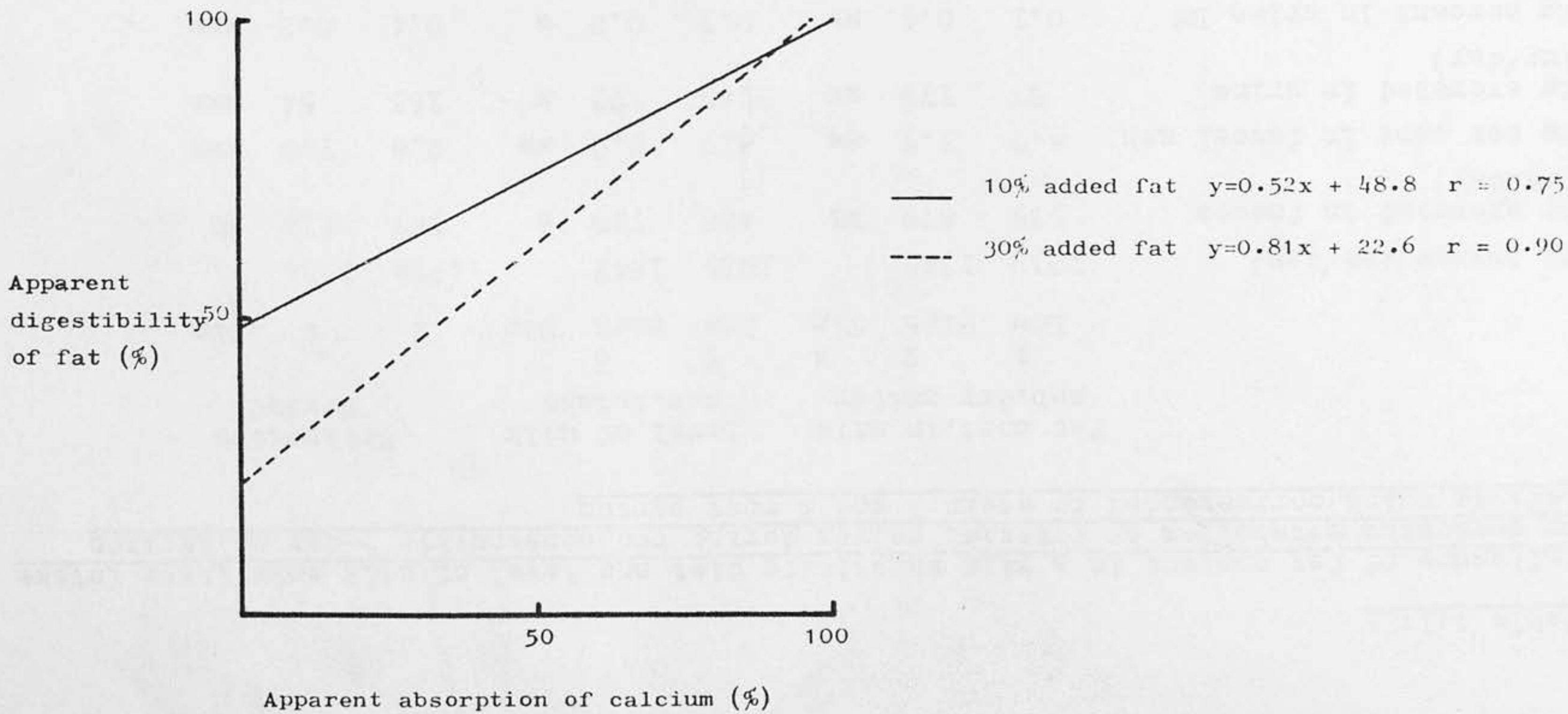


Table 4:1:11

Influence of fat content in a milk substitute diet and level of milk substitute intake on magnesium metabolism by Friesian calves during two consecutive 5-day collection periods which corresponded by weeks 3 and 4 post partum

	Fat cont.in milk sub.dry matter			Level of milk sub.intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
Mg intake (mg/day)	1239	1345		1026	1542		1234	1334	
Mg excreted in faeces (mg/day)	535	670	NS	466	719	*	567	618	NS
Mg per cent in faecal ash	6.0	3.5	**	3.9	5.9	**	2.8	7.0	***
Mg excreted in urine (mg/day)	57	179	**	145	73	*	165	54	***
Mg percent in urine DM	0.1	0.4	**	0.3	0.2	*	0.4	0.2	***
Total Mg excreted(mg/day)	592	849	*	611	793	NS	732	672	NS
Mg excreted in faeces as %age total Mg excreted	89.7	79.3	**	79.3	91.2	**	78.2	92.3	***
Mg absorbed as %age Mg intake	57.0	50.5	NS	54.7	53.8	NS	54.3	54.1	NS
Mg retention (mg/day)	647	496	NS	415	749	**	503	662	**
Mg retention as %age Mg intake	51.8	35.6	*	40.6	49.1	NS	39.8	49.9	*

1 to 6 See Table 4:1:1 for explanation

of Mg retention by calves fed the HF diet resulted from more Mg being excreted in both urine and faeces by these calves. Only the difference in urinary excretion of Mg was, however, significant between the two groups. The daily excretion of urine was less for calves fed the HF diet than those fed the LF diet and, therefore, the concentration of Mg in urine dry matter by these calves was higher than the concentration of Mg in urine dry matter by calves fed the LF diet. The route of excretion of Mg by calves fed the two diets differed; of the total Mg excreted by calves fed the LF diet, 90% was excreted in the faeces, and by calves fed the HF diet, 79% was excreted in the faeces.

Neither the efficiency of absorption nor the efficiency of retention of Mg was affected by the level of intake of milk substitute, but in absolute terms more Mg was absorbed and retained by calves fed at the high level of milk substitute intake than by calves fed at the low level of milk substitute intake.

There was also a marked increase in the retention and efficiency of retention of Mg with age mainly as a result of a reduction in the urinary excretion of Mg with age.

4:1:12 Sodium metabolism (Table 4:1:12)

Of the total Na excreted by calves fed the HF diet, 56% was excreted in the faeces compared with 4% excreted in the faeces by calves fed the LF diet. When the excretion of Na in the faeces reaches one gramme per day it is normally thought that the animal has diarrhoea (Blaxter and Wood, 1953). Calves fed the HF diet approached this level of faecal excretion of Na, but the dry matter content of their faeces was normal at 17%. (When the dry matter content of the faeces from calves is less than 10% these calves are considered to have diarrhoea.) Because of the high excretion rate of Na in the faeces of calves fed the HF diet, it follows that the efficiency of Na absorption was also lower by these animals compared with those fed the LF diet. Although less Na was absorbed by calves fed the HF diet these animals also excreted less Na in urine than did the calves fed the LF diet.

The level of milk substitute intake does not appear to have influenced the rate of absorption of Na, but calves fed at the high level of intake excreted relatively more Na in the urine than calves fed at the low level of

Table 4:1:12

Influence of fat content in a milk substitute diet and level of milk substitute intake on sodium metabolism by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat cont. in milk sub.dry matter			Level of milk sub.intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
Na intake (mg/day)	2247	1715		1615	2423		1939	2100	
Na excreted in faeces (mg/day)	83	714	*	292	414	NS	358	348	NS
Na percent in faecal ash	0.73	3.72	*	2.07	1.95	NS	1.29	2.73	*
Na excreted in urine (mg/day)	2120	722	***	1146	1895	**	1285	1756	*
Na percent in urine DM	4.33	2.01	***	2.61	4.06	***	2.75	3.92	*
Total Na excreted(mg/day)	2203	1436	**	1438	2309	**	1644	2104	**
Na excreted in faeces as %age total Na excreted	4.4	55.6	***	32.6	20.0	NS	30.3	22.4	NS
Na absorbed as %age Na intake	96.1	58.3	**	79.5	80.3	NS	80.2	79.6	NS

1 to 6 See Table 4:1:1 for explanation

intake.

There appears to be a significant increase in the rate of Na excreted in the urine with age.

4:1:13 Potassium metabolism (Table 4:1:13)

Absorption of K by calves fed the HF diet was significantly less than by calves fed the LF diet.

Age does not appear to have influenced the metabolism of K.

Table 4:1:13

Influence of fat content in a milk substitute diet and level of milk substitute intake on potassium metabolism by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat cont. in milk sub.dry matter			Level of milk sub.intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
K intake (mg/day)	8325	6257		5949	8928		7141	7736	
K excreted in faeces (mg/day)	449	1408	**	868	852	NS	964	756	NS
K percent in faecal ash	4.00	7.03	*	5.67	4.93	NS	4.43	6.17	*
K excreted in urine (mg/day)	6819	3428	***	4666	6065	***	5136	5595	NS
K percent in urine DM	13.98	9.08	***	10.93	12.83	**	11.23	12.53	NS
Total K excreted (mg/day)	7268	4836	***	5534	6917	**	6101	6351	NS
K excreted in faeces as %age total K excreted	6.5	28.6	**	17.5	14.4	NS	16.1	15.8	NS
K absorbed as %age of K intake	94.3	76.6	**	84.0	89.4	NS	85.5	87.9	NS

1 to 6 See Table 4:1:1 for explanation

4:1:14 Phosphorus metabolism (Table 4:1:14)

The absorption and retention of P was lower by calves fed the HF diet than by calves fed the LF diet and also was lower by those calves fed at the low level of milk substitute intake than by those fed at the high level of milk substitute intake.

Table 4:1:14

Influence of fat content in a milk substitute diet and level of milk substitute intake on phosphorus metabolism by Friesian calves during two consecutive 5-day collection periods which corresponded to weeks 3 and 4 post partum

	Fat cont. in milk sub. dry matter			Level of milk sub. intake			Collection Period		
	1 Low	2 High	4 Sig	5 Low	6 High	Sig	1	2	Sig
P intake (mg/day)	5071	4114		3726	5596		4474	4847	
P excreted in faeces (mg/day)	706	1103	NS	926	825	NS	907	844	NS
P percent in faecal ash	7.52	5.32	*	7.49	5.66	*	4.08	9.07	***
P excreted in urine (mg/day)	1899	1847	NS	1905	1848	NS	1903	1850	NS
P percent in urine DM	3.89	5.09	NS	4.66	4.15	NS	4.18	4.64	NS
Total P excreted (mg/day)	2604	2950	NS	2832	2673	NS	2811	2694	NS
P excreted in faeces as %age total P excreted	26.8	36.9	*	32.8	29.3	NS	31.6	30.6	NS
P absorbed as %age of P intake	84.8	72.5	*	74.5	84.5	*	77.8	81.2	NS
P retention (mg/day)	2467	1165	**	894	2923	***	1663	2154	*
P retention as %age P intake	46.6	24.0	*	22.3	51.6	**	33.1	40.8	NS

1 to 6 See Table 4:1:1 for explanation

4:2 Experiment 2

This experiment was carried out in Trinidad using Holstein and Zebu calves which were fed milk substitute diets containing 10% (LF), 20% (MF), and 30% (HF) added fat at a low (LI) and high (HI) level of milk substitute intake during one balance period, which comprised three collection periods (CP 1, 2 and 3) each of five days duration.

Introduction

Of a total of 12 Zebu calves, which were allocated to the experiment, three died at one, four and five weeks of age respectively. All three animals were particularly difficult to train to drink reconstituted milk substitute diets from a bucket. The first animal which died did not consume any milk before it died, and the other two animals had to be force-fed using a rubber nipple attached to a bottle. No pathological condition was apparent on post mortem examination of the first animal, and death was attributed to general weakness. Post mortem examination of the other two animals revealed that the cause of death was pneumonia. Three replacement Zebu calves were obtained and allocated to the experiment.

Difficulties were experienced in training all Zebu calves to drink reconstituted milk substitute diets from a bucket. The only Zebu calf which adapted to this system was three weeks of age before it would consume the diet without assistance or encouragement, and on average Zebu calves required assistance for approximately six weeks before they would consume these diets from a bucket, without assistance. During this period the reconstituted milk substitute diets were fed from a bottle using a rubber nipple. Even using this method these calves did not consume the reconstituted milk diets voluntarily, and the rubber nipple had to be rotated in the animal's mouth constantly so that a continuous, slow supply of milk was obtained by the calf. By this method four of the Zebu calves fed at the low level of milk substitute intake consumed the quantity of milk laid down by the experiment but two did not and of the six calves offered milk substitute diets at the high level of intake, only one consumed the quantity laid down by the experiment. The net intakes of reconstituted milk substitute diets by all Zebu calves were recorded.

No problems were experienced in the adaptation of Holstein calves to the system of rearing, nor did any death occur with Holstein calves.

4:2:1 Digestibility of dry matter (Table 4:2:1)

The apparent digestibility of dry matter by calves decreased as the fat content of the diet increased. Also the excretion of dry matter in urine decreased as the fat content of the diet increased. As in experiment 1, more than half the total dry matter excreted was excreted in urine.

Table 4:2:1

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on the excretion and digestion of dry matter (DM) by Holstein and Zebu calves during three consecutive 5-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst.intake				Breed				Collection period				
	Low [1]	Med. [2]	High [3]	SED [4]	Sig [5]	Low [6]	High [7]	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
DM intake (g/day)	581	559	577			430	714			642	362			508	604	604		
DM in faeces (%)	21.1	25.6	25.5	1.5	**	24.5	23.7	1.2	NS	22.7	28.2	1.4	***	25.0	22.9	24.3	1.0	NS
Excretion of DM in faeces (g/day)	19.7	25.8	31.9	3.5	**	20.9	30.7	2.8	**	27.2	21.5	3.3	NS	19.7	28.9	28.9	1.7	***
Excretion of DM in urine (g/day)	33.3	28.8	26.1	2.2	**	23.9	34.9	1.8	***	32.4	20.5	2.0	***	26.3	30.4	31.5	1.0	***
Total excretion of DM (g/day)	53.0	54.6	58.0	4.9	NS	44.8	65.6	4.0	***	59.6	42.0	4.7	***	46.0	59.3	60.4	2.0	***
App. digestibility of DM (%)	96.5	95.1	94.2	0.5	***	95.1	95.4	0.4	NS	95.7	94.0	0.5	***	96.0	94.8	94.9	0.3	***

1 Milk substitute dry matter containing 10% added fat

2 Milk substitute dry matter containing 20% added fat

3 Milk substitute dry matter containing 30% added fat

4 SED denotes standard error of the difference between means

5 NS denotes not significant, * denotes $P<0.05$, ** denotes $P<0.01$, *** denotes $P<0.001$.

6 Intake of reconstituted milk substitute equivalent to 10% of birth weight per day

7 Intake of reconstituted milk substitute equivalent to 15% of birth weight per day during collection period 1, and 20% of birth weight per day during collection periods 2 and 3.

The apparent digestibility of dry matter was not affected by the level of milk substitute intake. In absolute terms, however, those calves fed at the high level of milk substitute intake digested more dry matter than those fed at the low level of milk substitute intake.

Dry matter was digested more efficiently by Holstein than by Zebu calves, but the difference was small and could be accounted for by the difference in food intake between breeds.

4:2:2 Live weight increase (Table 4:2:2)

The rate of live weight increase was not affected by the level of fat in the milk substitute diet, but was affected by the level of intake and by the breed of calf (Table 4:2:2:1).

Table 4:2:2:1

The influence of level of milk substitute intake and breed of calf on mean daily live weight increase during a 3-week period (kg)

	Holstein	Zebu
Low level of milk intake	0.25	0.07
High level of milk intake	0.65	0.05

Table 4:2:2

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on the daily live weight increase by Holstein and Zebu calves during a three week balance period which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk substitute dry matter					Level of milk substitute intake				Breed			
	1	2	3	4	5	6	7						
	Low	Med.	High	SED	Sig	Low	High	SED	Sig	Hol.	Zebu	SED	Sig
Live weight increase (kg/day)	0.38	0.34	0.34	0.04	NS	0.20	0.50	0.04	***	0.45	0.66	0.04	***

1 to 7 See Table 4:2:1 for explanation

Live weight increase by Holstein calves fed at the high level of milk substitute intake was significantly greater than at the low level of milk substitute intake. However, no difference was observed in live weight increase between Zebu calves fed at the two levels of milk substitute intake. This is not surprising because five of the six Zebu animals allocated to the high level of milk substitute intake group did not consume the quantity of milk offered (Table 4:2:2:2).

Table 4:2:2:2

Mean quantities of dry matter ingested daily by Holstein and Zebu calves fed at the low and high levels of milk substitute intake during a 3-week period (g)

	Holstein	Zebu
Low level of milk intake	458	346
High level of milk intake	826	377

4:2:3 Nitrogen metabolism (Table 4:2:3)

The apparent digestibility of nitrogen was high for all calves, but was affected significantly by the level of fat in the diet and the breed of calf (Table 4:2:3:1)

Table 4:2:3:1

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Table 4:2:3

The influence of fat content in a milk substitute diet and of milk substitute intake and breed of calf on nitrogen (N) metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1	2	3	4	5	6	7											
	Low	Med.	High	SED	Sig	Low	High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
N intake(g/day)	30.1	26.1	23.1			19.9	33.0			29.7	16.6			23.5	27.9	27.9		
N excretion in faeces(g/day)	1.4	1.6	1.8	0.2	NS	1.2	1.9	0.2	***	1.7	1.3	0.2	NS	1.3	1.8	1.6	0.1	***
N percent in faecal DM	7.0	6.2	5.7	0.4	**	6.2	6.4	0.3	NS	6.3	6.2	0.4	NS	7.0	6.3	5.6	0.2	***
App.digestibility of N	95.3	93.8	91.8	0.7	***	93.5	93.8	0.5	NS	94.1	92.2	0.6	**	94.0	93.0	93.9	0.5	NS
N excreted in urine (g/day)	10.7	8.4	6.9	0.6	***	8.1	9.3	0.5	*	9.2	7.0	0.6	**	7.2	8.8	10.0	0.3	***
N percent in urine DM	34.0	31.1	27.7	1.9	***	34.1	27.7	1.5	*	29.4	35.6	1.8	***	27.8	31.0	34.0	0.9	***
Total N excreted (g/day)	12.1	9.9	8.7	0.7	***	9.3	11.2	0.6	**	10.9	8.3	0.7	***	8.5	10.6	11.6	0.3	***
N retention (g/day)	18.0	16.2	14.4	1.3	*	10.6	21.8	1.0	***	18.9	8.3	1.2	***	15.0	17.3	16.3	0.4	***

contd....

Table 4:2:3 contd.

	Fat content of milk subst. dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
N retention as %age N intake	55.6	57.9	58.8	2.9	NS	53.0	61.9	2.4	***	61.6	45.1	2.8	***	61.2	57.8	53.4	2.1	***
N excreted in urine as %age total N excreted	88.6	84.6	79.6	1.8	***	86.0	82.6	1.4	*	84.1	84.8	1.7	NS	84.0	82.7	86.1	1.0	***
N excreted in urine as %age total N intake	39.7	35.9	33.0	2.9	NS	40.5	21.9	2.4	***	32.6	47.1	2.7	***	32.9	35.3	40.5	1.9	***

1 to 7 See Table 4:2:1 for explanation

Table 4:2:3:1

Apparent digestibility of nitrogen in milk substitute diets, the dry matter of which contained 10%, 20% and 30% added fat by Holstein and Zebu calves during a 15-day balance period (%)

	Holstein	Zebu
Diet containing 10% fat	96.0	93.2
Diet containing 20% fat	94.2	92.7
Diet containing 30% fat	92.2	90.8

In absolute terms, nitrogen retention by calves decreased with increasing fat content of the diet fed. Because there was also a decrease in nitrogen intake with increasing fat content of the diet fed, the efficiency of nitrogen retention was similar between the different groups of calves.

The absolute nitrogen retention and the efficiency of nitrogen retention was higher for calves fed at the high level of milk substitute intake than those fed at the low level of milk substitute intake. Zebu calves retained less nitrogen and the efficiency of nitrogen retention was lower by Zebu than by Holstein calves. While no significant difference was observed between collection periods 1, 2 and 3 in the apparent digestibility of nitrogen, there was a trend of decreasing efficiency of nitrogen retention from collection period 1 to collection period 3 (Table 4:2:3:2).

Table 4:2:3:2

The influence of level of milk substitute intake on nitrogen retention as a percentage of nitrogen intake by Holstein and Zebu calves during three consecutive 5-day collection periods (%)

	Holstein			Zebu		
Collection period	1	2	3	1	2	3
Low milk intake	58.1	52.6	51.6	56.4	47.0	45.7
High milk intake	71.2	70.4	65.4	45.0	46.1	30.3

Regressions were calculated of the relationship between nitrogen excretion in faeces and nitrogen intake by Holstein and Zebu calves (Fig. 4:2:1). By extrapolation of these regressions the nitrogen excretion in faeces, when nitrogen intake is zero, can be determined for Holstein and Zebu calves as being 0.40g and -0.45g/day respectively. The correlation coefficient of the regression for Holsteins was low at 0.55.

Regressions were also calculated of the relationship between urinary nitrogen excretion and apparently digested nitrogen intake (Fig. 4:2:2). By extrapolation,

Fig. 4:2:1 Relationship between nitrogen intake and nitrogen excreted in the faeces by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets during a 15-day balance period.

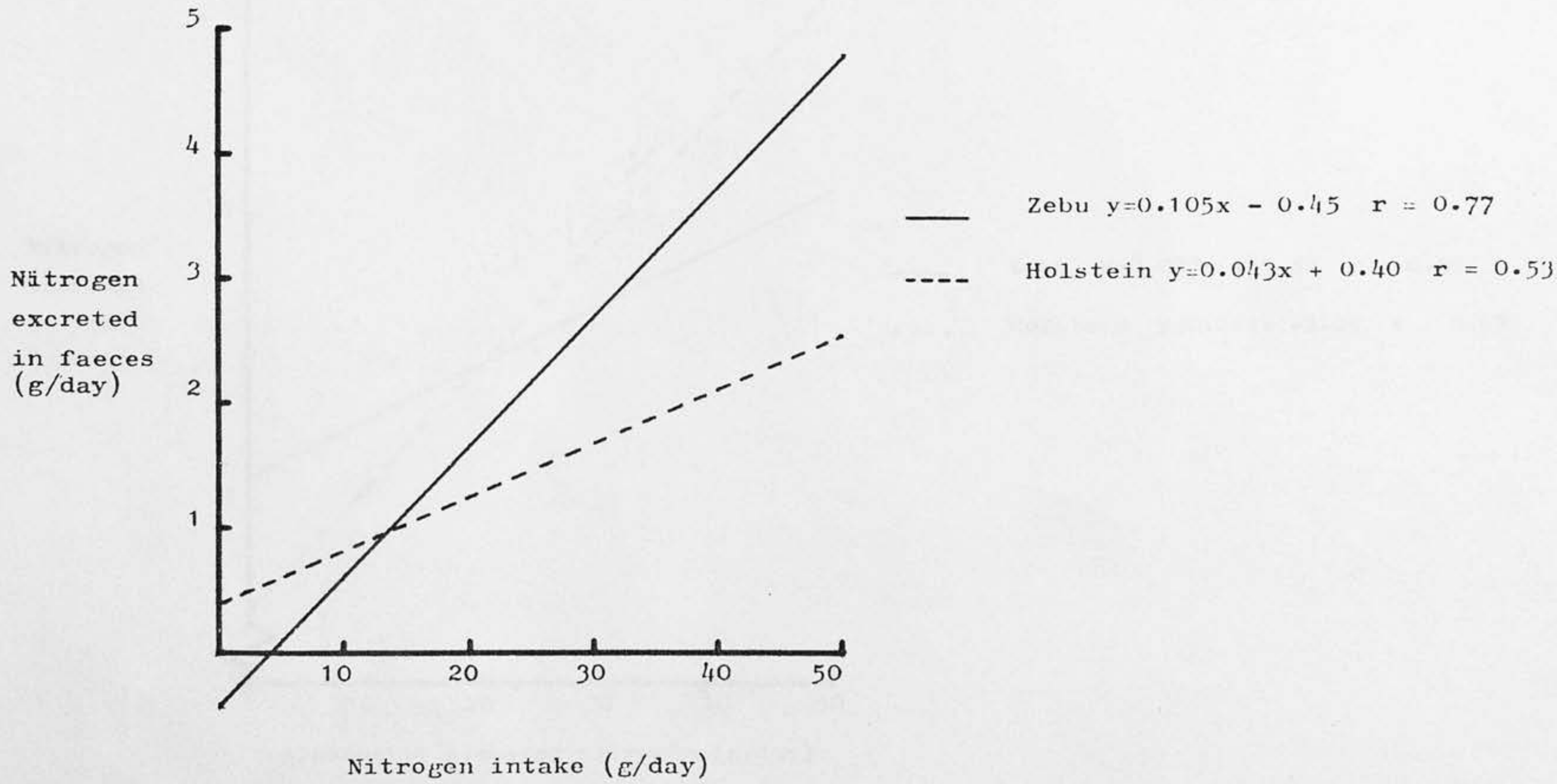
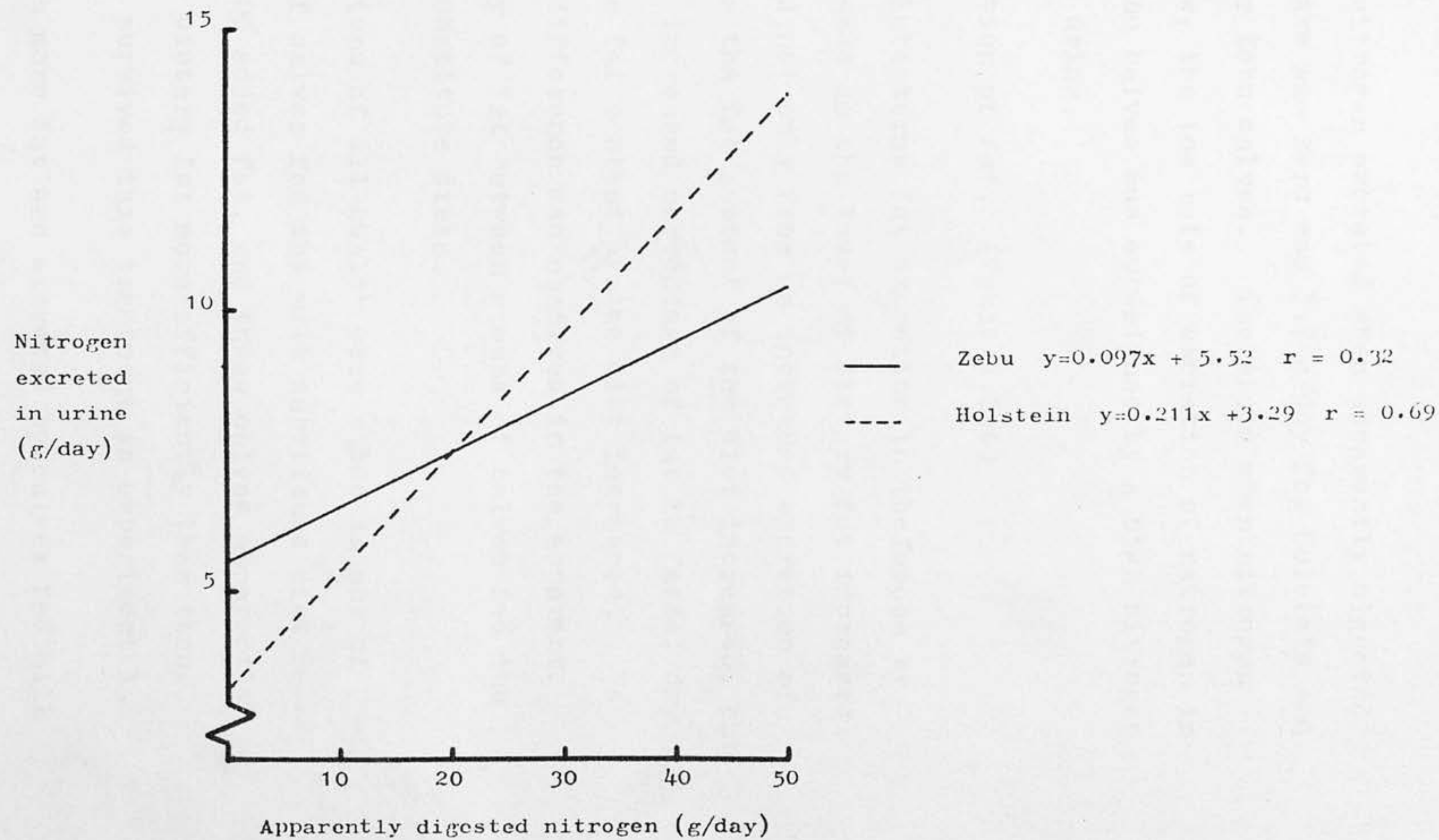


Fig. 4:2:2 Relationship between apparently digested nitrogen and nitrogen excreted in urine by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets during a 15-day balance period.



the urinary nitrogen excreted when apparently digested nitrogen intake was zero was 3.29g/day for Holstein and 5.52g/day for Zebu calves. Therefore when nitrogen intake is low, the low rate of excretion of nitrogen in faeces by Zebu calves was outweighed by a high nitrogen excretion in urine.

4:2:4 Digestion of fat. (Table 4:2:4)

In absolute terms fat excretion in the faeces by calves increased as the level of dietary fat increased. This resulted not only from an increased excretion of dry matter as the fat content of the diet increased, but also from an increased percentage of fat in faecal dry matter as the fat content of the diet increased. No significant difference was observed in the apparent digestibility of fat between groups of calves fed the three milk substitute diets.

No symptoms of ill-health were noted in any of the groups of calves fed the milk substitute diet containing 30% added fat, and these calves apparently digested the dietary fat more efficiently than those calves which survived this treatment in experiment 1.

Although more fat was excreted by calves fed milk substitute diets at the high level of intake than by calves

Table 4:2:4

Influence of fat content in a milk substitute diet level of milk substitute intake and breed of calf on excretion and digestibility of fat by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 & 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Fat intake (g/day)	71.5	118.4	180.8			93.6	153.5			138.2	79.7			109.4	130.5	130.8		
Fat excreted in faeces (g/day)	5.1	10.9	15.6	1.8	***	8.6	12.5	1.4	**	11.6	7.5	1.7	*	7.4	12.1	12.2	0.8	***
Fat percent in faecal DM	25.0	40.5	47.8	2.1	***	37.6	38.0	1.7	NS	40.1	30.9	2.0	***	34.7	38.9	39.7	1.1	***
App.digestib-ility of fat(%)	93.0	90.6	91.1	1.1	NS	91.3	91.8	0.9	NS	91.7	91.1	1.0	NS	93.5	90.7	90.6	0.6	***

1 to 7 See Table 4:2:1 for explanation

fed at the low level of intake, the apparent digestibility of fat by both groups of calves was similar. Also, the apparent digestibility of fat by Holstein and Zebu calves was similar.

4:2:5 Absorption of ash (Table 4:2:5)

While the apparent absorption of ash by calves fed the HF diet was significantly lower than by calves fed the LF or MF diets, the difference in the efficiency of ash absorption between calves fed the HF and LF diets was much less than the difference recorded in experiment 1.

The level of intake of milk substitute did not appear to affect the absorption of ash, but Zebu calves absorbed less ash and the efficiency of absorption of ash was lower by Zebu than by Holstein calves, also the apparent absorption of ash decreased with age.

4:2:6 Digestion of organic matter (Table 4:2:6)

The apparent digestibility of organic matter was affected by the level of fat in the diet fed, the breed and age of calves. There was a decrease in the apparent digestibility of organic matter as the level of dietary fat increased; Holstein calves digested organic

Table 4:2:5

Influence of fat content in milk substitute diet, level of milk substitute intake and breed of calf on excretion and absorption of ash by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 & 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Ash intake (g/day)	42.0	36.4	32.2			27.7	46.1			41.5	23.2			32.8	38.9	38.9		
Ash excreted in faeces (g/day)	3.9	4.1	4.9	0.6	NS	3.6	5.0	0.5	**	4.3	4.2	0.6	NS	2.9	4.8	5.2	0.3	***
Ash percent in faecal DM	19.9	16.6	15.2	1.1	***	17.6	16.9	0.9	NS	16.3	20.0	1.0	***	15.5	17.3	18.9	0.5	***
App. absorption of ash (%)	90.1	86.9	83.7	1.7	**	86.6	87.2	1.4	NS	88.8	81.2	1.6	***	90.0	85.8	84.9	0.9	***

1 to 7 See Table 4:2:1 for explanation

Table 4:2:6

Influence of fat content in milk substitute diet level of milk substitute intake and breed of calf on excretion and digestibility of organic matter by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 & 5 post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake				Breed				Collection period				
	1	2	3	4	5	6	7											
	Low	Med.	High	SED	Sig	Low	High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
OM intake(g/day)	539	522	544			403	668			601	338			476	565	56 5		
Om excreted in faeces (g/day)	15.9	21.7	27.0	2.9	**	17.3	25.7	2.4	***	22.9	17.4	2.7	NS	16.7	24.2	23.6	1.4	***
App. digestib-ility of OM(%)	97.0	95.6	94.8	0.5	***	95.6	96.0	0.4	NS	96.1	94.9	0.9	**	96.4	95.4	95.6	0.3	**

1 to 7 See Table 4:2:1 for explanation

matter better than Zebu calves, and during collection period 1, the apparent digestibility of organic matter was higher than in the other two collection periods. In spite of these differences, the apparent digestibility of organic matter was high for all calves.

4:2:7 Digestion of nitrogen free extractives (Table 4:2:7)

Nitrogen free extractives were apparently digested better by calves fed the HF diet than by calves fed either the LF or the MF diet.

Holstein calves digested nitrogen free extractives more efficiently than Zebu calves, but the apparent digestibility of nitrogen free extractives was very high for all animals.

4:2:8 Energy metabolism (Table 4:2:8)

The indirect method of estimating gross energy values of samples (See section 3:4) resulted in an over-estimate of the gross energy content of foodstuffs, but under-estimated the gross energy content of faeces, compared with actual calorific values obtained by using a bomb calorimeter. The actual calorific values of the food-stuffs were approximately 96% of the calculated values, while the calculated calorific values of faecal samples were 86-89% of actual values. The actual apparent

Table 4:2:7

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on excretion and digestibility of Nitrogen free extractives (NFE) by Holstein and Zebu calves during 3 consecutive five-day collection periods which corresponded to weeks 3, 4 & 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1	2	3	4	5	6	7											
	Low	Med.	High	SED	Sig	Low	High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
NFE intake(g/day)	275	237	216			182	303			273	153			216	256	256		
NFE excreted in faeces(g/day)	1.84	0.74	0.01	0.39	***	0.88	0.85	0.32	NS	0.62	1.61	0.37	*	0.77	0.67	1.15	0.33	NS
App. digestibility of NFE(%)	99.2	99.4	99.9	0.2	*	99.5	99.5	0.2	NS	99.8	98.7	0.2	***	99.6	99.6	99.4	0.2	NS

1 to 7 See Table 4:2:1 for explanation

Table 4:2:8

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on energy metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Gross energy intake(kcal/day)	2745	2911	3277			2244	3711			3344	1879			2647	3141	3145		
Energy excreted in faeces(kcal/day)	120	190	243	27	***	145	224	22	**	200	138	26	*	142	207	204	14	***
App.digestib. of energy (%)	95.6	93.4	92.3	0.7	***	93.6	93.9	0.6	NS	94.0	92.9	0.7	NS	94.7	93.2	93.4	0.4	**
Energy excrt.in urine(kcal/day)	58	45	37	3.1	**	44	50	3.0	*	50	38	3.1	***	39	48	54	1.0	***
Metabolisable energy (kcal/day)	2567	2676	2997	184	*	2055	3437	150	**	3094	1703	173	***	2466	2886	2887	35	***
Metabolisable energy as %age of gross energy intake	93.5	91.9	91.5	0.92	NS	91.6	92.6	0.75	NS	92.5	90.6	0.86	NS	93.2	91.9	91.8	0.56	***

1 to 7 See Table 4:2:1 for explanation

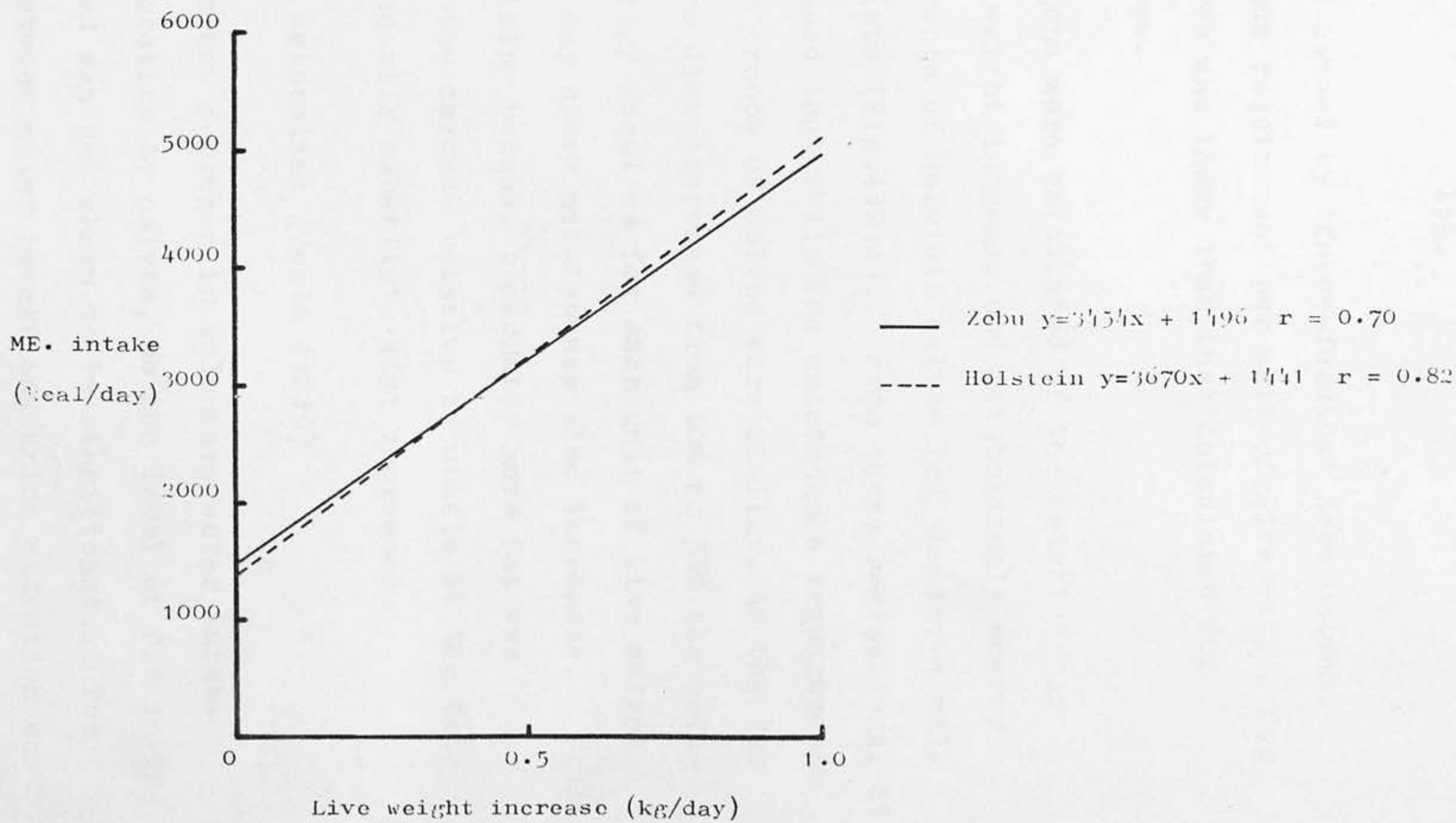
digestibility of energy was, therefore, marginally lower than the apparent digestibility of energy using indirectly calculated values. In all treatment groups, metabolisable energy was equal to approximately 98% of digested energy.

The efficiency of energy digestion decreased as the fat content of the diet increased. Also, the energy excreted in urine decreased as the fat content of the diet increased. In absolute terms the metabolisable energy was lowest when determined using calves fed the LF diet, and was highest when determined using calves fed the HF diet, but metabolisable energy as a percentage of gross energy intake was similar for all three diets.

Metabolisable energy as a percentage of gross energy intake was higher when calves were fed at the high rate of milk substitute intake, than at the low rate of milk substitute intake. In absolute terms, Zebu calves excreted less energy in their faeces and urine than Holstein calves, but this was a function of the lower gross energy intake by Zebu calves than by Holstein calves. Both energy digested and energy metabolised as a percentage of gross energy intake were similar for both breeds. Energy was digested and metabolised better in collection period 1 than in collection periods 2 and 3, indicating a decrease in the efficiency of energy metabolism with age.

Regressions were calculated of the relationship between live weight increase and metabolisable energy (ME) intake by Holstein and Zebu calves (Fig 4:2:3). From these regressions the metabolisable energy required for maintenance (i.e. at zero live weight increase) was 1441 and 1496 kcal/day for Holstein and Zebu calves respectively, and the metabolisable energy required for one kilogramme live weight increase was 3670 and 3454 kcal/day respectively. The energy requirement for maintenance, therefore, appears to be similar for Holstein and Zebu calves, but on a unit live weight basis the energy required for maintenance was 32 kcalME/kg live weight/day for Holstein calves and 58 kcalME/kg live weight/day for Zebu calves. Because metabolisable energy was 98% of the digested energy, the requirement for maintenance in terms of digested energy was 33 kcal/kg live weight/day for Holstein calves, and 59 kcal/kg live weight/day for Zebu calves. On a unit metabolic body weight basis the metabolisable energy required for maintenance was 89.5 kcalME/kg$^{0.73}$/day for Holstein calves, and 138.6 kcalME/kg$^{0.73}$/day for Zebu calves. While the maintenance requirement per unit live weight for Zebu calves was higher than that found for Holstein calves and for Friesian calves in experiment 1, but the difference

Fig. 4:2:3 Relationship between live weight increase and metabolisable energy intake by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets during a 15-day balance period.



may have been caused by 'force-feeding' Zebu calves. The maintenance requirement per unit of live weight for Holstein calves was lower than that calculated for Friesian calves.

Regressions were calculated of the relationship between live weight increase and metabolisable energy intake for groups of Holstein calves fed the three milk substitute diets (Fig.4:2:4). From these regressions, it can be concluded that while the maintenance requirements for all three groups of calves were similar, as the fat content of the diet increased from 10% to 30% the metabolisable energy required for each unit of live weight increase per day above maintenance also increased. This is not surprising because presumably more fat was deposited in the carcase relative to muscle as the fat content of the milk substitute diet increased.

4:2:9 Water metabolism (Table 4:2:9)

The apparent decrease in voluntary water intake and urine excretion by calves, as the level of fat in the diet increased was not shown to be significant. The difference between water intake and urine excretion was greater for calves fed at the high level of milk substitute intake than for calves fed at the low level of milk substitute intake.

Fig. 4:2:4 Relationship between live weight increase and metabolisable energy intake by Holstein calves between 3 and 5 weeks of age when fed three milk substitute diets containing 10%, 20% and 30% added fat during a 15-day balance period.

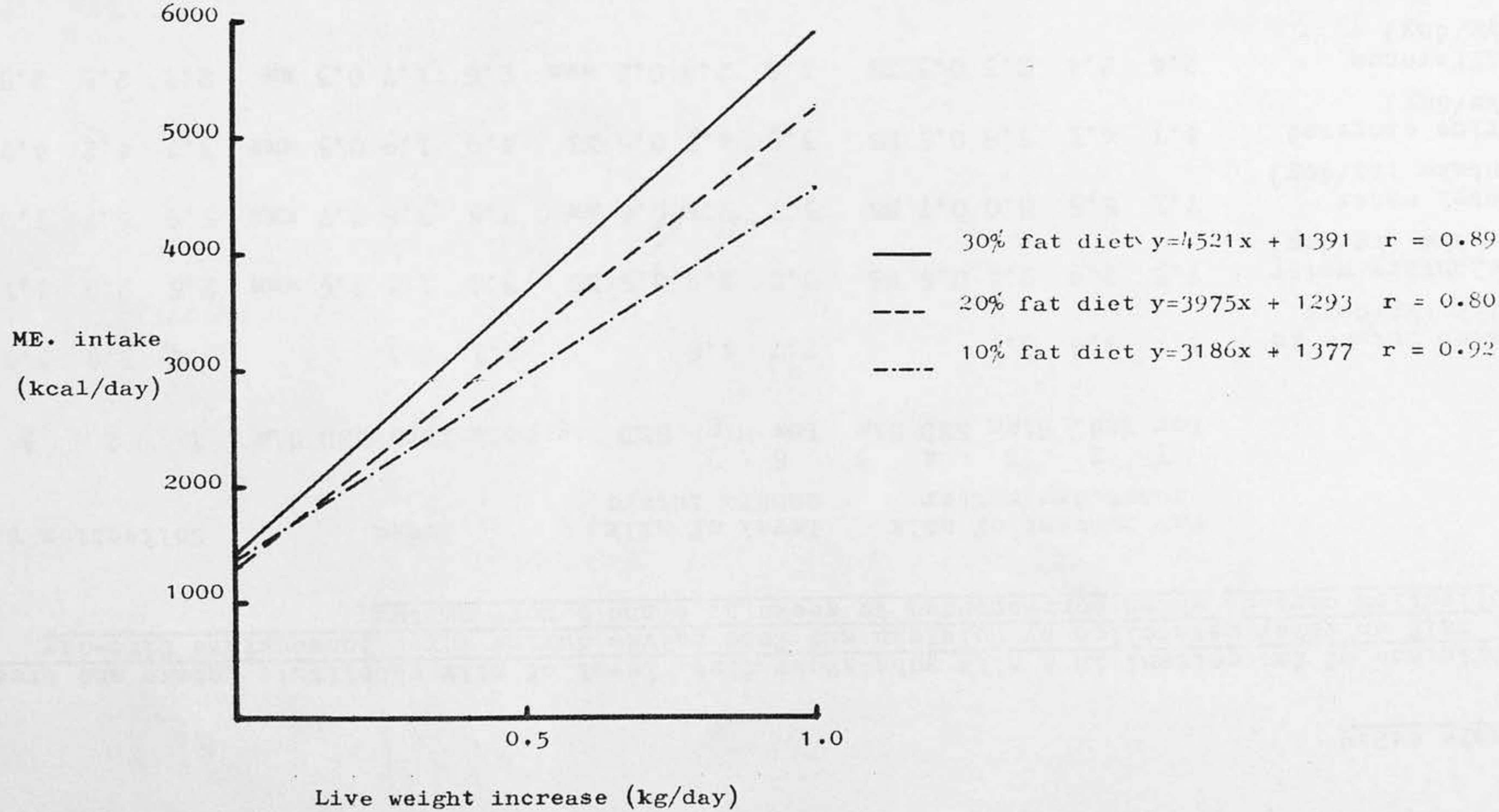


Table 4:2:9

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on water metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	SED	Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Water intake in milk (kg/day)	3.7	3.6	3.6			2.7	4.6			4.1	2.3			3.2	3.9	3.9		
Voluntary water intake (kg/day)	3.3	2.9	2.4	0.6	NS	3.0	2.8	0.5	NS	3.4	1.3	0.6	***	2.6	2.9	3.1	0.1	**
Total water intake (kg/day)	7.1	6.5	6.0	0.7	NS	5.7	7.4	0.6	**	7.5	3.6	0.7	***	5.9	6.7	7.0	0.1	***
Urine excreted (kg/day)	4.7	4.1	3.8	0.6	NS	3.9	4.5	0.5	NS	4.9	1.9	0.5	***	3.7	4.2	4.7	0.1	***
Difference (kg/day)	2.4	2.4	2.3	0.3	NS	1.8	2.9	0.2	***	2.6	1.7	0.3	**	2.2	2.5	2.3	0.1	**

1 to 7 See Table 4:2:1 for explanation

Voluntary water intake was much lower by Zebu than by Holstein calves (1.3 vs 3.4 kg/day). Excretion of urine was also much lower for Zebu than for Holstein calves (1.9 vs 4.9kg/day) and the difference between total water intake and urine excretion was significantly less for Zebu than for Holstein calves (1.7 vs 2.6kg/day). The ratio of total daily water intake: total daily urine excretion was, however, similar at 9.9:1 for Zebu, and 11.7:1 for Holstein calves. Voluntary water intake increased with age, as did urine excretion.

4:2:10 Heart rates and rectal temperatures (Table 4:2:10)

During all balance periods, the heart rates and rectal temperatures of all calves were measured at weekly intervals, five hours after the morning feed.

Heart rates were affected by all four variables studied, and treatment group means ranged from 75.5 beats/min for Zebu calves on treatment LFLI during CP3, to 124.7 beats/min for Holstein calves on treatment HFHI during CP1.

Rectal temperatures were not affected by the level of fat in the diet, or by the age of calf, but were affected by the breed of calf and the level of food intake. The range of rectal temperatures was from 101.2 for Zebu calves fed at the low level of food intake, to 101.9 for Holstein calves fed at the high level of food intake.

Table 4:2:10

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on heart rates and rectal temperatures of Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk Subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Heart rates (beats/min)	91.8	94.4	105.0	3.3	***	85.6	108.6	2.7	***	99.9	88.6	3.1	***	101.8	98.7	90.8	1.9	***
Rectal temperatures (^oF)	101.5	101.6	101.7	0.1	NS	101.4	101.8	0.1	***	101.7	101.3	0.1	***	101.6	101.7	101.5	0.1	NS

1 to 7 See Table 4:2:1 for explanation

4:2:11 Calcium metabolism (Table 4:2:11)

Significantly more Ca was retained by calves fed the milk substitute diet containing ten per cent added fat than by calves fed either of the other two milk substitute diets. Similarly, more Ca was retained by calves fed at the high level of milk substitute intake than by calves fed at the low level of milk substitute intake, but again the efficiency of retention of Ca by calves was similar between these two groups.

Although the efficiency of Ca absorption and retention was similar between Holstein and Zebu calves, the route of excretion of Ca differed between breeds. Of the total Ca excreted 96% was excreted in the faeces by Holstein calves, while only 90% was excreted in the faeces by Zebu calves. Also the concentration of Ca in urine dry matter was higher for Zebu than for Holstein calves.

The apparent absorption and retention of Ca was greater in the first collection period than in the second and third collection periods.

Linear regressions were calculated for the relationship between Ca absorbed and fat digested by all groups of calves fed the three milk substitute diets. (Fig.4:2:5)

Table 4:2:11

Influence of fat content in milk substitute diet, level of milk substitute intake and breed of calf on calcium metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1	2	3	4	5	6	7											
	Low	Med.	High	SED	Sig	Low	High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Ca intake(mg/day)	6260	5675	5673			4414	7324			6591	3705			5218	6192	6198		
Ca excreted in faeces(mg/day)	778	921	1057	157	NS	795	1042	128	NS	1012	639	148	*	625	1019	1112	62	***
Ca percent in faecal ash	23.5	21.7	21.9	4.0	NS	24.3	20.4	3.3	NS	24.6	15.6	3.8	*	24.4	21.3	21.4	3.9	NS
Ca excreted in urine(mg/day)	49.5	29.7	41.4	12.5	NS	36.9	43.5	10.2	NS	37.5	48.1	11.8	NS	31.2	45.9	43.5	7.1	NS
Ca in urine DM%	0.18	0.12	0.15	0.04	NS	0.16	0.14	0.03	NS	0.12	0.22	0.04	*	0.13	0.16	0.16	0.03	NS
Total Ca excreted (mg/day)	828	951	1098	161	NS	832	1086	132	NS	1049	687	152	*	656	1064	1156	63	***
Ca excreted in faeces as %total Ca excreted	92.1	95.9	95.1	1.7	NS	94.0	94.7	1.4	NS	95.8	90.1	1.6	***	92.4	95.2	95.4	1.3	*

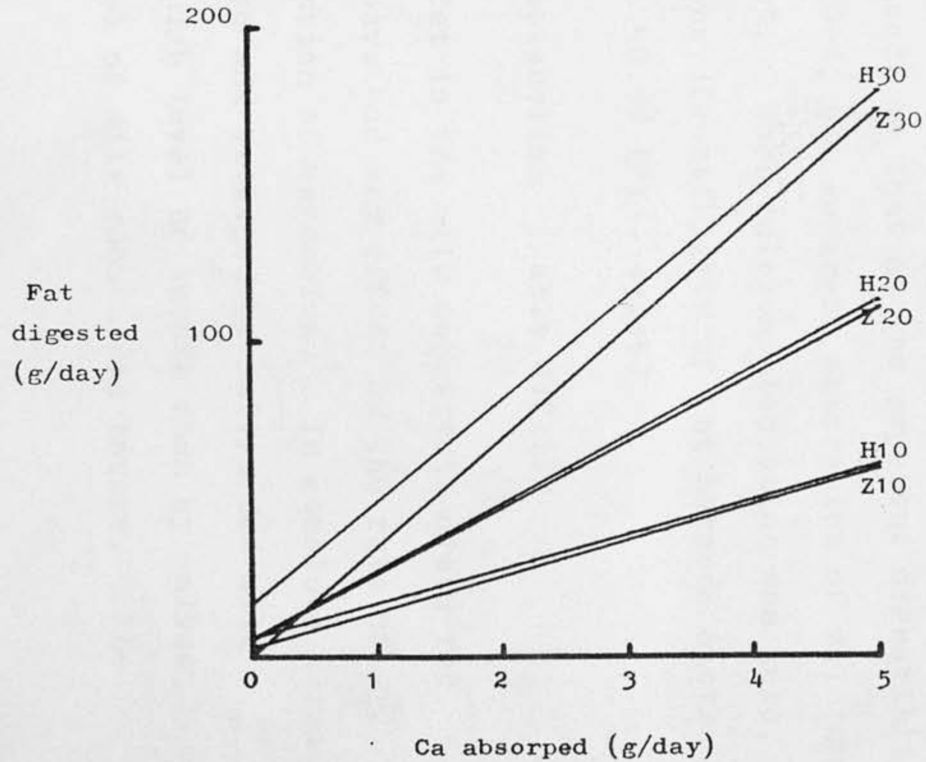
contd...

Table 4:2:11 contd.

	Fat content of milk subst. dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
App. absorption of Ca(%)	86.9	83.0	81.0	2.5	NS	81.9	85.4	2.1	NS	84.0	82.6	2.4	NS	87.8	82.3	80.8	1.1	***
Ca retention (mg/day)	5432	4724	4575	352	*	3583	6238	288	***	5541	3018	332	***	4562	5128	5042	82	***
Ca retention as %age Ca intake	85.9	82.4	80.2	2.5	NS	81.0	84.7	2.1	NS	83.3	81.4	2.4	NS	87.1	81.5	80.0	1.1	***

1 to 7 See Table 4:2:1 for explanation

Fig. 4:2:5 <u>Relationship between calcium absorped and fat digested by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 15-day balance period</u>.



H30 $y=32.26x + 18.72$ $r = 0.98$
Z30 $y=34.84x + 0.19$ $r = 0.99$

H20 $y=21.54x + 5.37$ $r = 0.99$
Z20 $y=20.93x + 6.09$ $r = 0.97$

H10 $y=10.93x + 6.95$ $r = 0.99$
Z10 $y=11.44x + 2.99$ $r = 0.98$

H = Holstein

Z = Zebu

The number following each letter indicates the fat content of the diet.

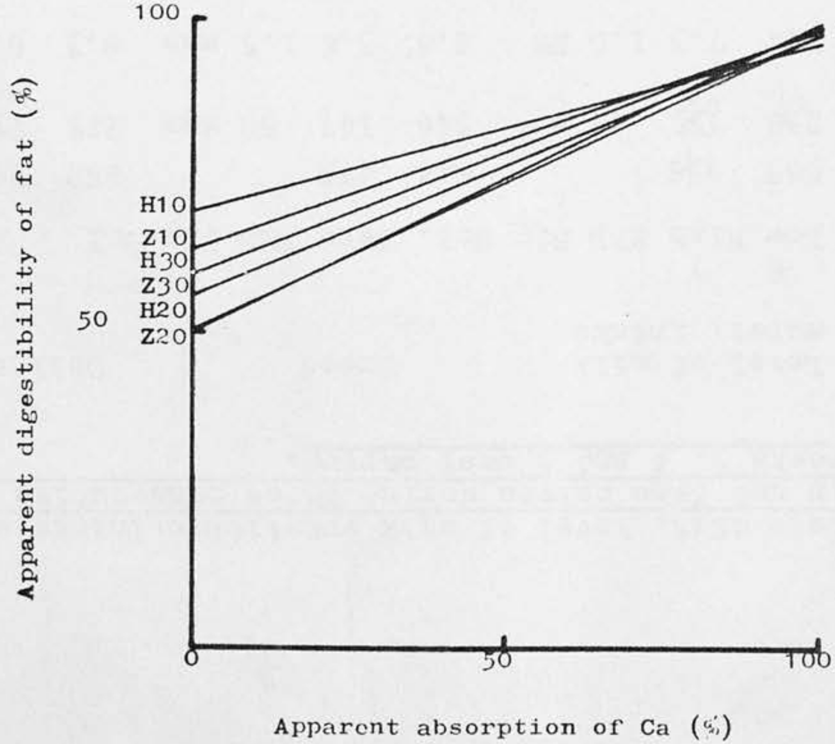
Considerably more calcium was absorbed relative to fat digested by calves fed the LF diet than those calves fed the HF diet, the calves fed the MF diet were intermediate. The relationship between calcium absorption and fat digestion was similar for breeds of calves fed each of the three diets. The difference between diets would, therefo e, appear to result from the original difference in the absolute amounts of fat ingested.

With all of the diets fed, however, as the apparent digestibility of fat increased, the apparent absorption of calcium also increased, so that as the apparent digestibility of fat approached 100%, the apparent absorption of calcium also approached 100%. When calcium absorption was zero, however, the apparent digestibility of fat between diets varied from 69.4 to 50.3% (Fig. 4:2:6)

4:2:12 Magnesium metabolism (Table 4:2:12)

The level of fat in the milk substitute diets fed did not appear to have had any effect on the rate of absorption or retention of magnesium. In absolute terms more Mg was absorbed and retained by calves fed milk substitute at the high level of intake than by calves fed at the low level of milk substitute intake. The

Fig. 4:2:6 Relationship between apparent absoprtion of Ca and apparent digestibility of fat by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 15-day balance period.



H10	$y=0.27x + 69.4$	$r = 0.68$
Z10	$y=0.35x + 63.3$	$r = 0.25$
H30	$y=0.39x + 59.7$	$r = 0.96$
Z30	$y=0.42x + 56.2$	$r = 0.75$
H20	$y=0.47x + 51.0$	$r = 0.86$
Z20	$y=0.49x + 50.3$	$r = 0.83$

H = Holstein

Z = Zebu

The number following each letter indicates the fat content of the diet.

Table 4:2:12

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on magnesium metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum.

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Mg intake (mg/day)	806	717	732			565	938			844	475			668	793	794		
Mg excreted in faeces (mg/day)	287	299	302	54	NS	238	355	43	*	346	147	50	***	225	298	366	19	***
Mg percent in faecal ash	8.7	7.1	6.2	1.3	NS	7.4	7.3	1.0	NS	8.6	3.6	1.3	***	8.3	6.5	7.2	1.2	NS
Mg excreted in urine (mg/day)	148	142	145	21	NS	120	171	17	**	165	86	19	***	167	148	120	11	***
Mg in urine DM%	0.5	0.5	0.6	0.06	NS	0.5	0.5	0.05	NS	0.5	0.4	0.05	*	0.6	0.5	0.4	0.04	***
Total Mg excreted (mg/day)	435	441	447	51	NS	357	526	42	***	511	233	48	***	392	446	486	20	***
Mg excreted in faeces as %age total Mg excreted	61.6	64.5	63.6	5.0	NS	63.0	63.5	4.1	NS	64.5	59.4	4.7	NS	52.1	64.8	72.8	2.4	***

contd....

Table 4:2:12 contd.

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
App.absorption of Mg (%)	64.7	59.4	58.8	6.3	NS	59.0	62.9	5.2	NS	58.1	69.4	6.0	NS	67.5	62.0	53.3	2.5	***
Mg retention (mg/day)	371	276	285	48	NS	208	412	39	***	333	242	45	NS	276	347	308	20	**
Mg retention as % Mg intake	45.3	38.7	38.4	5.9	NS	37.7	43.9	4.8	NS	37.6	50.5	5.6	*	41.7	43.0	37.7	2.6	NS

1 to 7 See Table 4:2:1 for explanation

efficiency of absorption of Mg was, however, similar between groups of calves fed at the high and low levels of milk substitute intake.

The intake of milk substitute (and hence Mg) was lower for Zebu calves than Holstein calves, and this resulted in less Mg being excreted in both the faeces and urine by Zebu calves. While the apparent absorption of Mg by Zebu and Holstein calves was similar, the efficiency of retention of Mg was significantly higher for Zebu calves. Of the total Mg excreted, 37% was excreted in the urine by Zebu calves, and 32% in urine by Holstein calves.

The Mg excreted in the faeces increased with age, and the Mg excreted in the urine decreased with age. More Mg was excreted in the faeces than in urine, and the Mg excreted in faeces as a percentage of total Mg excreted increased markedly with age from 52.1% in collection period 1, to 72.8% in collection period 3.

Regressions were calculated to describe the relationship between Ca and Mg retention and N, and Mg retention by Holstein and Zebu calves (Figs 4:2:7 and 4:2:8). The level of fat in the milk substitute diet does not appear to affect the retention of Ca or N

Fig. 4:2:7 <u>Relationship between magnesium and calcium retention by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 15-day balance period.</u>

H30	y=7.25x + 2861	r = 0.82
H20	y=8.18x + 3014	r = 0.80
H10	y=8.29x + 2825	r = 0.86
Z30	y=7.99x + 1277	r = 0.64
Z20	y=10.16x + 772	r = 0.65
Z10	y=8.54x + 879	r = 0.94

H = Holstein

Z = Zebu

The number following each letter indicates the fat content of the diet.

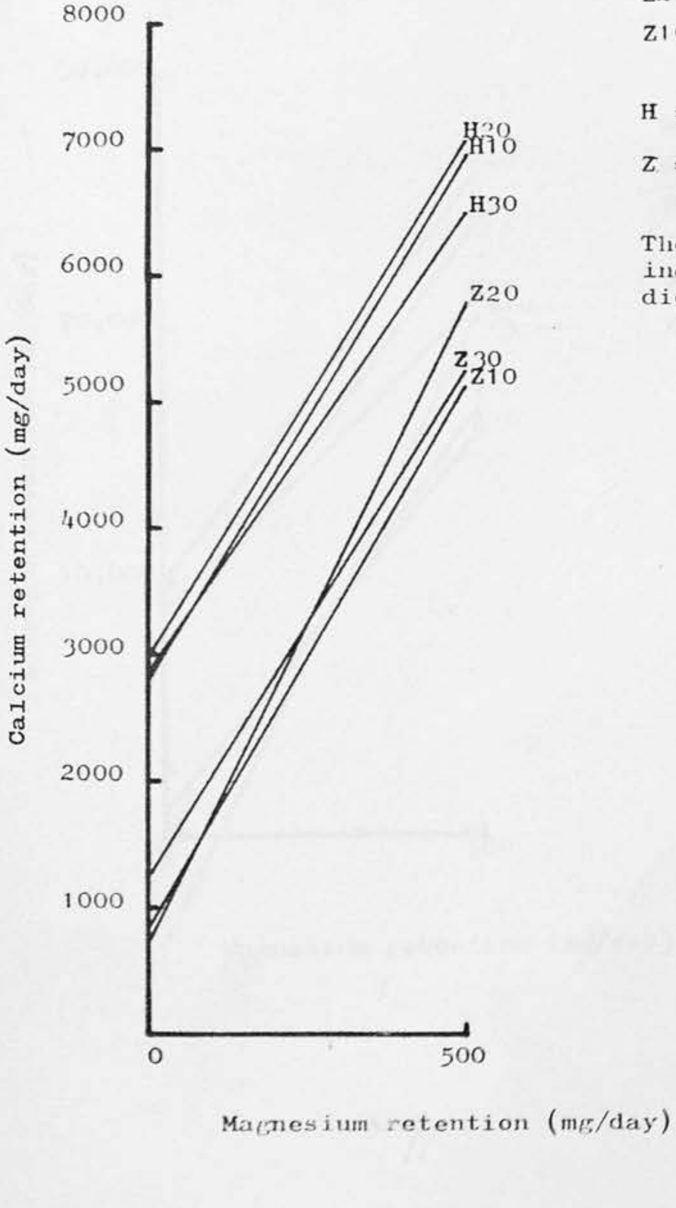
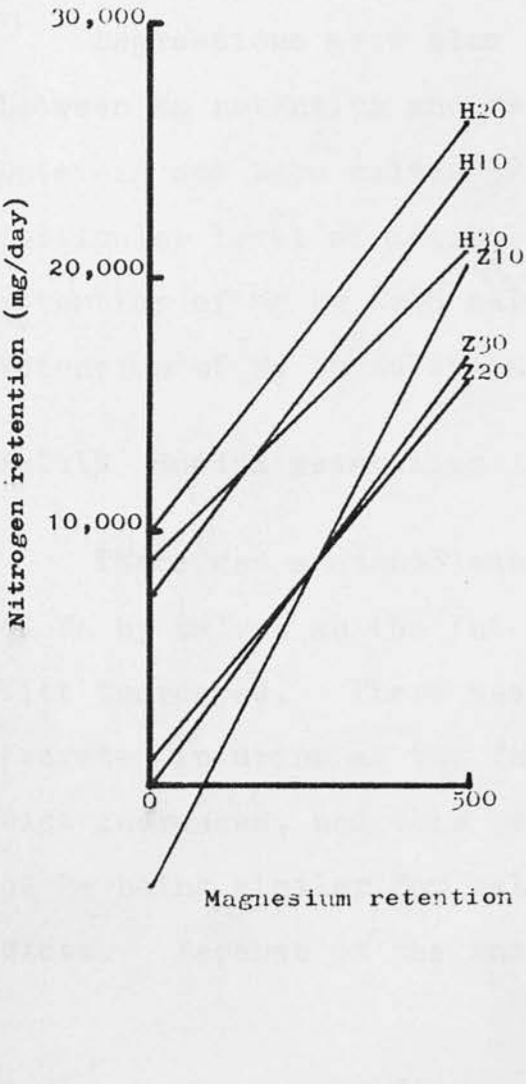


Fig. 4:2:8 <u>Relationship between magnesium and nitrogen retention by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 15-day balance period.</u>

H = Holstein

Z = Zebu

The number following each letter indicates the fat content of the diet.



H30	$y=24.6x + 8810$	$r = 0.70$
H20	$y=30.0x + 10205$	$r = 0.73$
H10	$y=33.4x + 7505$	$r = 0.83$
Z30	$y=33.7x + 210$	$r = 0.64$
Z20	$y=30.1x + 950$	$r = 0.83$
Z10	$y=50.5x - 4806$	$r = 0.97$

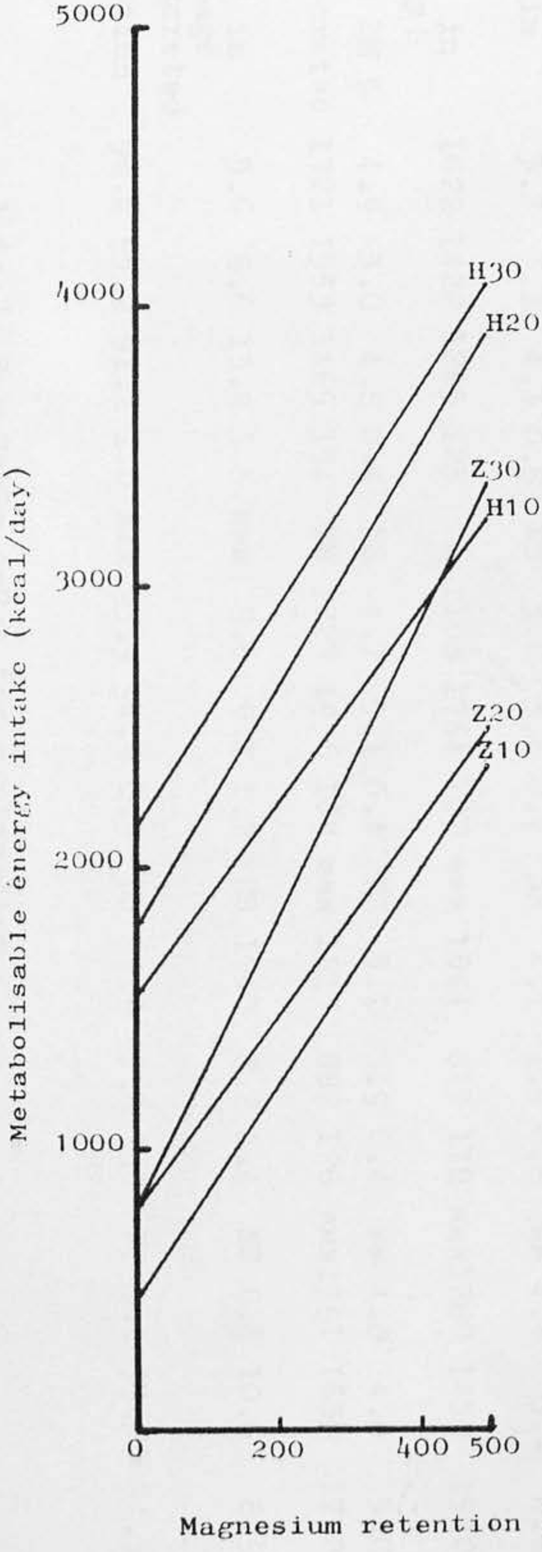
relative to the retention of Mg, but at any particular level of Ca or N retention significantly more Mg is retained by Zebu than by Holstein calves. For example, when Ca retention was approximately 3g/day, Mg retention by Holstein calves was zero, but Mg retention by Zebu calves was approximately 200-250mg/day. Similarly, when N retention was approximately 9g/day Mg retention by Holstein calves was zero, but Mg retention by Zebu calves was approximately 250mg/day.

Regressions were also calculated of the relationship between Mg retention and metabolisable energy intake by Holstein and Zebu calves (Fig. 4:2:9). At any particular level of metabolisable energy intake, the retention of Mg by Zebu calves was much higher than the retention of Mg by Holstein calves.

4:2:13 Sodium metabolism (Table 4:2:13)

There was a significant decrease in the absorption of Na by calves as the fat content of the milk substitute diet increased. There was, however, a decrease in the Na excreted in urine as the fat content of milk substitute diet increased, and this resulted in total excretion rates of Na being similar for calves fed the three milk substitute diets. Because of the increased excretion of Na in faeces

Fig. 4:2:9 Relationship between magnesium retention and metabolisable energy intake by Holstein and Zebu calves between 3 and 5 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 15-day balance period.



H30	$y=3.81x + 2171$	$r = 0.72$
H20	$y=4.20x + 1807$	$r = 0.75$
H10	$y=3.36x + 1561$	$r = 0.81$
Z30	$y=5.11x + 807$	$r = 0.62$
Z20	$y=3.40x + 807$	$r = 0.81$
Z10	$y=3.75x + 492$	$r = 0.92$

H = Holstein

Z = Zebu

The number following each letter indicates the fat content of the diet.

Table 4:2:13

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on sodium metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection Period				
	1	2	3	4	5	6	7											
	Low	Med.	High	SED	Sig	Low	High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
Na intake(mg/day)	2665	2628	2321			1908	3168			2853	1593			2256	2678	2680		
Na excreted in faeces(mg/day)	100	131	200	31	**	115	172	25	*	169	68	29	**	111	172	148	19	**
Na percent in faecal ash	3.2	3.1	4.3	0.8	NS	3.6	3.4	0.7	NS	4.1	1.8	0.8	**	4.4	3.4	2.8	0.7	NS
Na excreted in urine(mg/day)	1622	1422	1265	125	*	1108	1764	102	***	1644	813	118	***	1280	1459	1570	91	**
Na in urine DM %	4.9	5.0	4.8	0.4	NS	4.7	5.1	0.4	NS	5.2	3.9	0.4	**	4.8	4.8	5.0	0.3	NS
Total Na excreted (mg/day)	1721	1553	1465	134	NS	1223	1936	109	***	1813	882	126	***	1391	1630	1718	93	**
Na excreted in faeces as %age total Na excreted	5.6	8.6	13.9	1.5	***	9.6	9.1	1.2	NS	10.0	8.2	1.4	NS	8.6	10.6	8.9	1.0	NS
App. absorption Of Na (%)	96.6	95.2	91.2	1.0	***	93.9	94.8	0.9	NS	93.9	95.8	1.0	NS	95.1	93.5	94.5	0.7	NS

1 to 7 See Table 4:2:1 for explanation

and decreased excretion of Na in urine as the fat content of the milk substitute diet increased, the Na excreted in the faeces as a percentage of the total Na excreted rose from 6 - 14% as the fat content of the diet increased from 10% to 30%.

Although absorption of Na decreased with increasing fat content in the diet, the rate of absorption of Na was high and ranged from 91 - 97% between groups of calves.

The rate of Na excretion in faeces and urine was affected significantly by the level of milk substitute intake, and was higher for those calves fed at the high rate of intake than for those calves fed at the low rate of intake. This high excretion of Na appears to be only a function of intake.

The apparent absorption of Na was similar for Holstein and Zebu calves and differences between breeds in absolute excretion rates appeared to be merely a function of the difference in Na intake between Holstein and Zebu calves. The absorption of Na did not appear to be affected by age.

4:2:14 Potassium metabolism (Table 4:2:14)

Calves fed the milk substitute diet containing 30% added fat had a lower efficiency of absorption of K than calves fed either of the other two milk substitute diets. Calves fed the diet containing 30% fat were, in fact, in negative K balance.

Calves fed at the high level of milk substitute intake absorbed more K in absolute terms than calves fed at the low level of milk substitute intake, but the efficiency of absorption of K was similar for these two groups of calves.

The excretion of K in faeces and urine was higher by Holstein calves than by Zebu calves, but in view of the higher intake of K by Holstein calves, the efficiency of absorption of K by both breeds was similar. Age of the calf did not appear to affect the metabolism of K.

4:2:15 Phosphorus metabolism (Table 4:2:15)

While the efficiency of absorption of P was similar between calves fed the three milk substitute diets, the retention and the efficiency of retention of phosphorus

Table 4:2:14

Influence of fat content in a milk substitute diet, level of milk substitute intake and breed of calf on potassium metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake				Breed				Collection Period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
K intake(mg/day)	9483	9199	7016			6429	10702			9638	5348			7615	9039	9043		
K excreted in faeces(mg/day)	247	242	341	60	NS	197	356	49	**	302	199	57	NS	215	316	299	40	*
K percent in faecal ash	7.9	5.7	6.8	1.9	NS	6.7	6.9	1.5	NS	7.5	4.9	1.8	NS	8.7	6.2	5.5	1.8	NS
K excreted in urine(mg/day)	8551	7304	6697	562	**	5816	9218	458	***	8606	4252	530	***	6394	8069	8088	344	***
K in urine DM %	25.5	25.2	25.7	1.7	NS	24.6	26.4	1.4	NS	27.1	20.6	1.6	***	24.3	26.8	25.4	1.4	NS
Total K excreted (mg/day)	8798	7546	7038	580	*	6013	9575	473	***	8908	4451	547	***	6609	8385	8387	339	***
K excreted in faeces as %age total K excreted	2.8	3.4	5.0	0.7	**	3.3	4.1	0.6	NS	3.5	4.3	0.6	NS	3.5	4.0	3.8	0.5	NS
App. absorption of K (%)	97.6	97.4	94.9	0.8	**	96.7	96.5	0.7	NS	96.7	96.4	0.8	NS	97.1	96.2	96.5	0.5	NS

1 to 7 See Table 4:2:1 for explanation

Table 4:2:15

Influence of fat content in a milk substitute diet, level of milk substitute intake, and breed of calf on phosphorus metabolism by Holstein and Zebu calves during three consecutive five-day collection periods which corresponded to weeks 3, 4 and 5 post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake				Breed				Collection Period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
P intake (mg/day)	4773	4540	3538			3216	5351			4819	2677			3809	4520	4522		
P excreted in faeces (mg/day)	314	256	280	65	NS	306	261	53	NS	291	261	61	NS	227	323	301	37	*
P percent in faeceal ash	16.4	6.1	5.9	8.2	NS	13.9	5.1	6.7	NS	10.5	6.6	7.8	NS	15.7	6.7	6.2	7.8	NS
P excreted in urine (mg/day)	1865	1601	1625	168	NS	1391	2002	137	***	1858	1214	158	***	1379	1737	1974	85	***
P in urine DM %	5.7	5.7	6.3	0.4	NS	5.9	5.8	0.3	NS	5.9	5.9	0.4	NS	5.3	5.9	6.4	0.4	*
Total P excreted (mg/day)	2179	1857	1905	195	NS	1697	2264	159	***	2149	1474	184	***	1606	2060	2276	93	***
P excreted in faeces as %age total P excreted	14.6	14.7	14.7	2.6	NS	17.2	12.0	2.1	*	13.6	17.6	2.4	NS	13.7	15.6	14.6	1.6	NS

contd...

Table 4:2:15 contd.

	Fat content of milk subst. dry matter					Level of milk subst. intake				Breed				Collection Period				
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig	Hol.	Zebu	SED	Sig	1	2	3	SED	Sig
App.absorption of P (%)	92.3	93.1	91.5	1.8	NS	90.3	94.4	1.5	**	93.1	90.0	1.7	NS	93.4	91.7	91.9	1.1	NS
P retention (mg/day)	2594	2683	1633	221	***	1518	3088	180	***	2670	1202	208	***	2203	2460	2246	104	*
P retention as %age P intake	51.9	55.7	44.4	3.8	*	46.3	55.0	3.1	**	53.3	42.7	3.6	**	55.7	50.8	45.5	2.5	***

1 to 7 See Table 4:2:1 for explanation

was lower for calves fed the milk substitute diet containing 30% fat than for calves fed either of the other two diets. Calves fed at the high rate of milk substitute intake absorbed P more efficiently than calves fed at the low rate of milk substitute intake. Also, absolute retention and the efficiency of retention of P was higher by calves fed at the high rate of milk substitute intake than by calves fed at the low rate of milk substitute intake.

Holstein calves apparently absorbed and retained more P than Zebu calves, but Holstein calves also had a higher intake of P than Zebu calves, and as has been shown, the absorption and retention of P improved as intake increased. There was a tendency for absorption of P to decline with age. Also, the efficiency of retention of P declined with age from56% in CP1 to 46% in CP3.

4:3 Experiment 3

In experiment 3, which was carried out in Trinidad, 12 Zebu calves were fed milk substitute diets containing 10% (LF), 20% (MF) and 30% (HF) added fat at a low (LI) and high (HI) level of milk substitute intake. Collection periods of five days duration were carried through on all calves for each of the three milk substitute diets.

Introduction

On completion of experiment 2, each of the 12 Zebu calves was fed a milk substitute diet, which had the same composition as that fed to it during experiment 2, but the level of reconstituted milk substitute intake was increased to an amount equal to ten per cent of 35kg (the estimated mean birth weight of Holstein calves). The intention was that when Zebu calves had increased in live weight to 35kg a further balance trial comprising three five-day collection periods would be carried through on them to provide data on Zebu calves which could be compared with that already obtained from Holstein calves weighing 35kg.

Of the twelve Zebu calves in experiment 3, only seven could be described as being of comparable live weight to Holstein calves in experiment 2. Of these seven Zebu calves, four were fed at the low level of milk substitute intake and three were fed at the high level of milk substitute intake. The live weight increases of the remaining Zebu calves following the balance period in experiment 2 was approximately zero with no indication that they would ever increase in weight. With these calves, therefore, the second balance period was carried through inspite of them not having reached the live weight of 35kg. A cross-over technique was used in allocating Zebu calves to this second balance period. Details of the cross-over design have been described in section 3:3.

4:3:1 Digestibility of dry matter (Table 4:3:1)

The apparent digestibility of dry matter was lower for those calves fed the HF diet than for those calves fed the MF and LF diets. While more dry matter was excreted in the faeces by calves fed the HF diet than by calves fed the MF or LF diets, less dry matter was excreted in urine by calves fed the HF diet than by calves fed the MF or LF diets.

No significant difference could be shown in the apparent digestibility of dry matter or in the retention of dry matter between calves fed at the low and high levels of milk substitute intake.

4:3:2 Live weight increase (Table 4:3:2)

The mean daily live weight increase by calves fed the HF diet appeared to be lower than the daily live weight increase by calves fed the MF and LF diets, but

Table 4:3:1

Influence of fat content in a milk substitute diet and level of milk substitute intake on the excretion and digestion of dry matter (DM) during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
DM intake (g/day)	508	509	501			429	582		
DM in faeces (%)	27.4	30.5	31.0	1.7	NS	30.4	28.9	1.6	NS
DM excreted in faeces (g/day)	26.5	29.1	35.9	2.7	*	28.0	32.9	4.2	NS
DM excreted in urine (g/day)	30.9	26.6	24.9	1.9	*	23.9	31.0	7.2	NS
Total DM excreted (g/day)	57.4	55.7	60.8	4.3	NS	51.9	63.9	11.3	NS
App. digestibility of DM (%)	93.7	93.4	91.5	0.7	*	92.6	93.2	0.6	NS

1 Milk substitute dry matter containing 10% added fat

2 Milk substitute dry matter containing 20% added fat

3 Milk substitute dry matter containing 30% added fat

4 SED denotes standard error of the difference between means

5 NS denotes not significant, * denotes $P.<0.01$, ** denotes $P<0.01$, *** denotes $P<0.001$

6 Reconstituted milk substitute offered equivalent to 10% of live weight per day

7 Reconstituted milk substitute offered equivalent to 20% of live weight per day

Table 4:3:2

Influence of fat level in a milk substitute diet and level of milk substitute intake on the live weight increase during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Live weight increase (kg/day)	0.22	0.29	0.19	0.09	NS	0.14	0.33	0.20	NS

1 to 7 See Table 4:3:1 for explanation

no statistically significant difference between groups could be determined. Also, those calves fed at the high level of milk substitute intake appeared to have a higher daily live weight increase than those calves fed at the low level of milk substitute intake, but the difference was not statistically significant.

4:3:3 Nitrogen metabolism (Table 4:3:3)

The apparent digestibility of nitrogen was high for all calves, but was significantly lower for calves fed the HF diet compared with calves fed the MF and LF diets. Nitrogen excreted in urine by calves fed the HF diet was less than the nitrogen excreted in urine by calves fed the MF and LF diets. This resulted in there being no significant difference in the absolute retention of nitrogen between groups of calves fed the three types of milk substitute diet.

The efficiency of nitrogen retention was lower for calves fed at the high level of milk substitute intake than for those fed at the low level of milk substitute intake. (Table 4:3:3:1)

Table 4:3:3:1

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Table 4:3:3

<u>Influence of fat level in a milk substitute diet and level of milk substitute intake on nitrogen metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum.</u>

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
N intake (g/day)	26.4	23.7	20.1			19.8	27.0		
N excreted in faeces (g/day)	1.4	1.1	1.3	0.1	NS	1.1	1.5	0.3	NS
N in faecel dry matter (%)	5.6	4.4	3.8	0.2	***	4.7	4.5	0.6	NS
App. digestibility of N (%)	94.1	94.6	92.5	0.5	**	93.9	93.6	0.6	NS
N excreted in uring (g/day)	11.5	10.5	7.7	0.8	**	8.8	11.0	1.4	NS
Total N excreted (g/day)	12.9	11.6	9.0	0.9	**	9.9	12.5	1.7	NS
N retention (g/day)	13.5	12.1	11.1	1.0	NS	9.9	14.5	4.7	NS
N retention as %age N intake	44.1	41.5	44.4	7.4	NS	48.4	38.3	2.3	*
N excreted in urine as %age total N excreted	89.6	90.2	85.7	1.0	**	89.0	88.0	0.5	NS
N excreted in urine as %age total N intake	50.0	53.1	48.1	7.5	NS	45.6	55.3	2.1	*

1 to 7 See Table 4:3:1 for explanation

Table 4:3:3:1

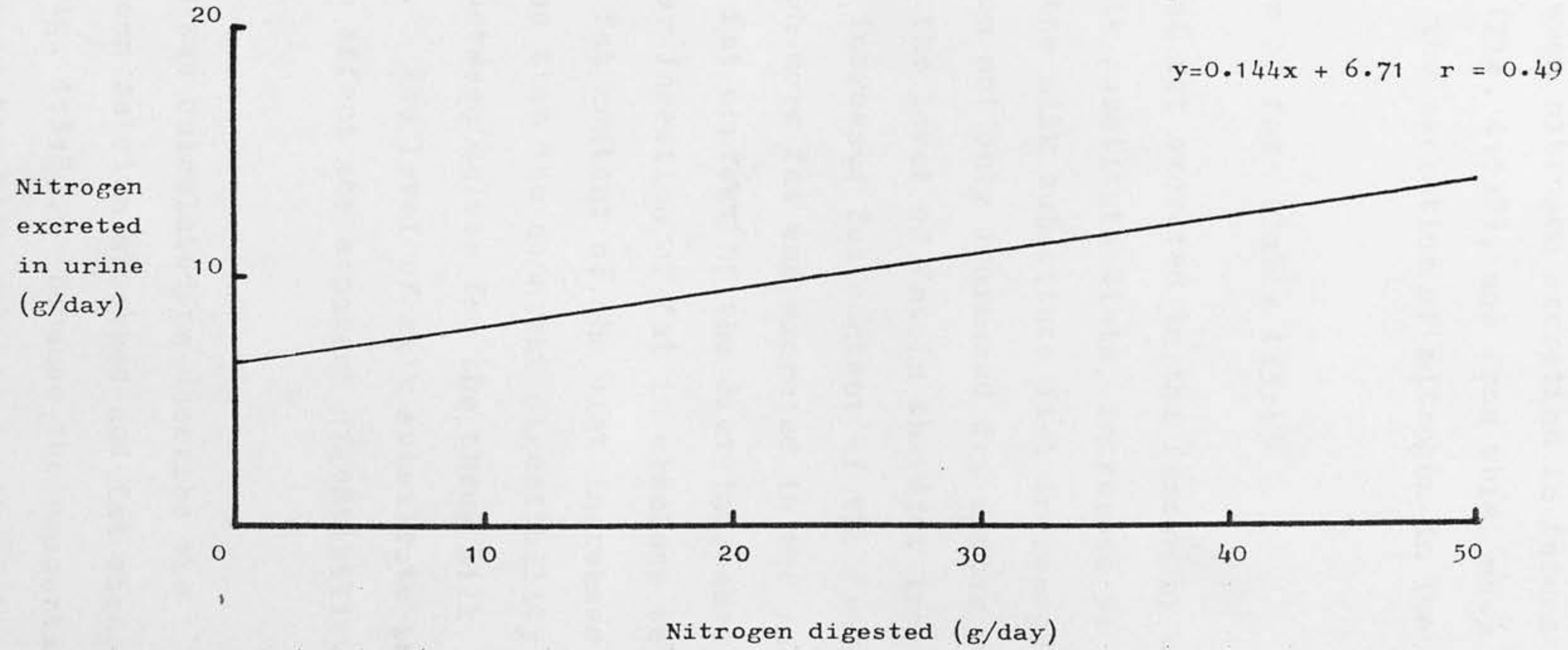
Nitrogen retention as a percentage of nitrogen intake by Zebu and Holstein calves fed milk substitute diets at two levels of intake during a 15-day balance period (%)

	Intake of milk substitute diet	
	Low	High
Zebu - experiment 2	49.7	40.5
Zebu - experiment 3	48.4	38.3
Holstein - experiment 2	54.1	69.0

The efficiency of nitrogen retention by Holstein calves increased with an increase in intake of milk substitute, but the reverse was the case with Zebu calves. It is impossible to assess to what extent this decrease in efficiency of nitrogen retention by Zebu calves resulted from the low voluntary food intake by these calves when offered food at the high level of intake, but it is likely that this was at least one of the factors, if not the main factor involved.

A regression was calculated of the relationship between urinary nitrogen excretion and apparently digested nitrogen intake (Fig 4:3:1). From this the nitrogen excreted in urine when the absorption of nitrogen was zero was found to be 6.7g/day.

Fig. 4:3:1 <u>Relationship between nitrogen digested and nitrogen excreted in the urine by Zebu calves which were approximately 10 weeks of age when fed milk substitute diets during a 15-day balance period</u>.



A regression was also calculated of the relationship between nitrogen excretion in faeces and nitrogen intake (Fig. 4:3:2), and from this, when nitrogen intake was zero, the excretion of nitrogen in the faeces was 600 mg/day.

4:3:4 Digestion of fat (Table 4:3:4)

The weight of fat excreted in the faeces by calves fed the three milk substitute diets, increased as the level of fat in the milk substitute diet increased. This resulted from not only increased dry matter excretion in the faeces as the level of fat in the diet increased, but also from an increased fat content of the faecal dry matter. Although more fat was excreted in the faeces by calves as the fat content of the diet increased, there was also a greater ingestion of fat in absolute terms by calves as the fat content of the diet increased. The overall result was that the apparent digestibility of fat was similar between calves fed the three milk substitute diets. The level of milk substitute intake did not appear to affect the apparent digestibility of fat.

A regression was calculated to describe the relationship between calcium absorbed and fat digested by Zebu calves (Fig. 4:3:3). Because the proportion of fat relative to Ca in the milk substitute diets increased

Fig. 4:3:2 Relationship between nitrogen intake and nitrogen excreted in the faeces by Zebu calves which were approximately 10 weeks of age when fed milk substitute diets during a 15-day balance period.

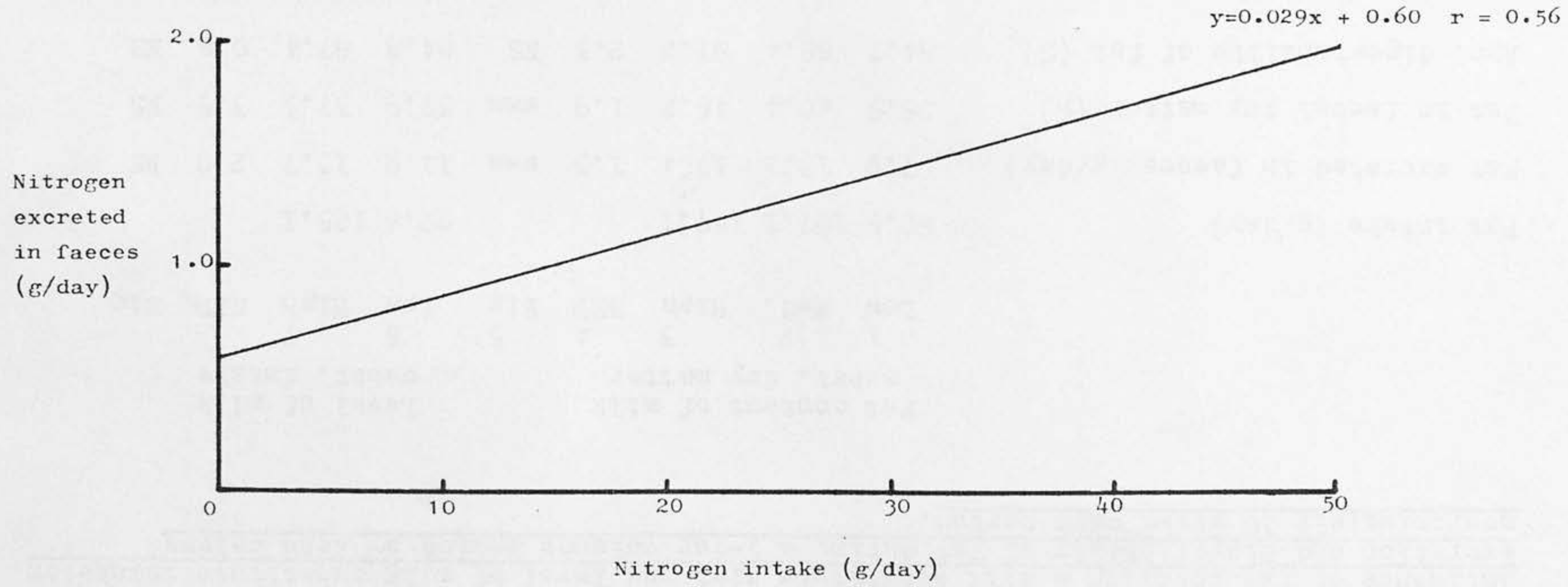


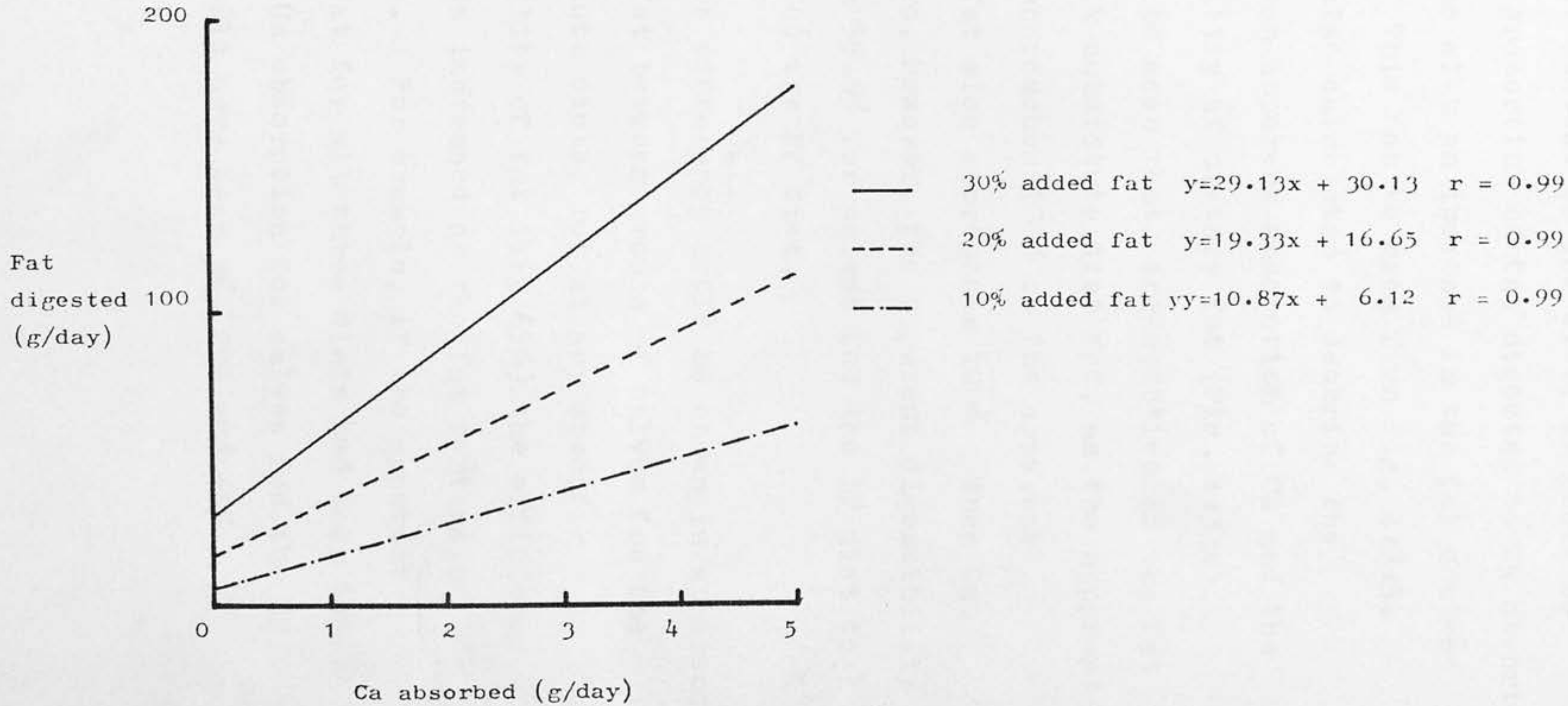
Table 4:3:4

Influence of fat level in a milk substitute diet and level of milk substitute intake on excretion and digestibility of fat during a 5-day balance period by Zebu calves approximately 10 weeks post partum.

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1	2	3	4	5	6	7		
	Low	Med.	High	SED	Sig	Low	High	SED	Sig
Fat intake (g/day)	62.5	107.1	157.1			92.8	125.1		
Fat excreted in faeces (g/day)	7.9	13.1	17.4	1.3	***	11.9	13.7	2.0	NS
Fat in faecal dry matter (%)	26.5	40.4	46.2	1.9	***	37.9	37.5	3.5	NS
App. digestibility of fat (%)	84.7	86.4	87.2	2.3	NS	84.8	87.4	0.8	NS

1 to 7 See Table 4:3:1 for explanation

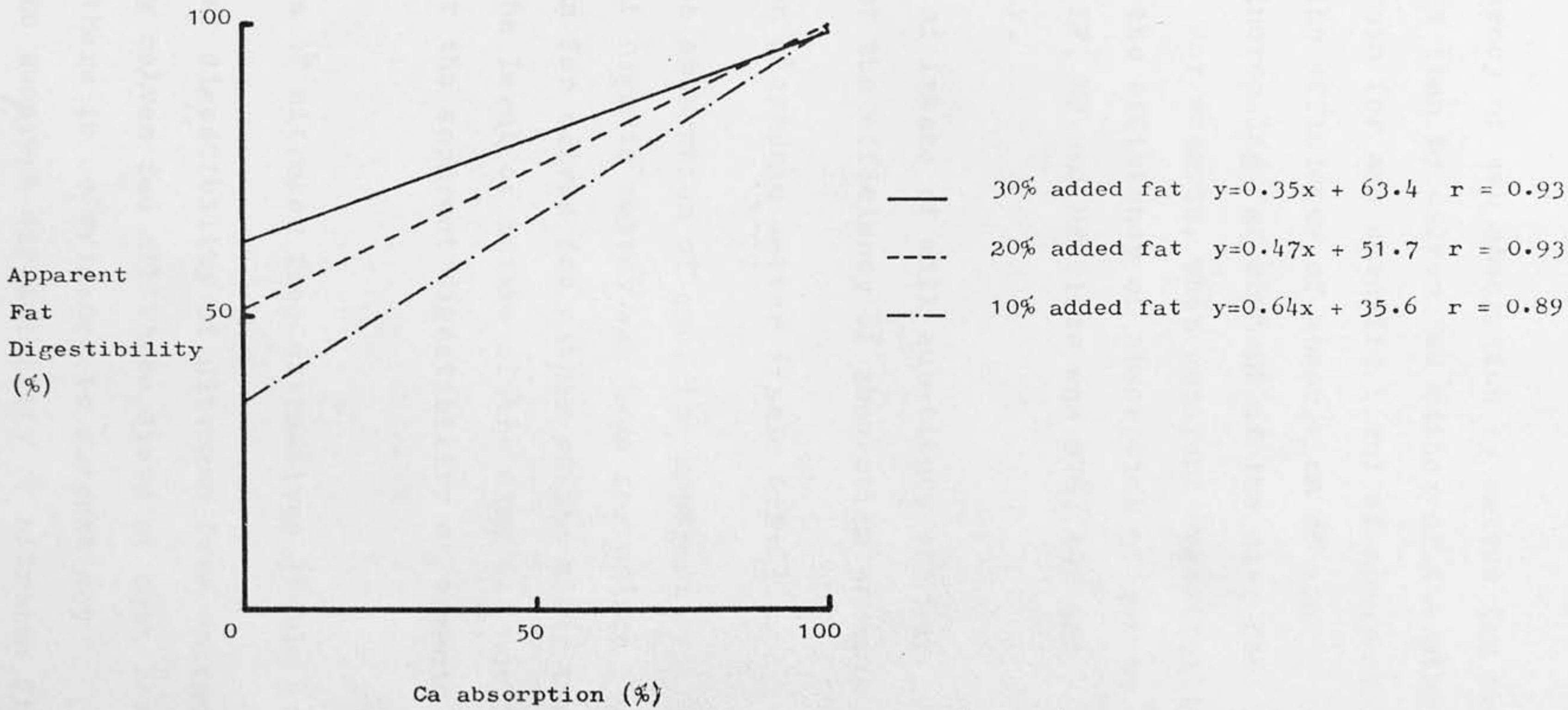
Fig. 4:3:3 Relationship between Ca absorption and fat digested by Zebu calves which were approximately 10 weeks of age when fed three milk substitute diets containing 10%, 20% and 30% added fat during a 5-day balance period.



with increasing fat content of the diet, it could be expected that the proportion of fat digested to Ca absorbed would also increase with an increase in the fat content of the diet fed. This can be seen from Fig. 4:3:3. Regressions were also calculated to describe the relationship between apparent absorption of Ca and the apparent digestibility of dietary fat (Fig. 4:3:4). From these it can be seen that, irrespective of the fat content of the milk substitute diet fed, as the apparent absorption of Ca approaches 100% so the apparent digestibility of fat also approaches 100% When Ca absorption was zero, however, the apparent digestibility of fat ranged from 35.6% for calves fed the LF diet to 63.4% for calves fed the HF diet.

No significant difference could be shown in apparent digestibility of fat between groups of calves fed the three milk substitute diets, but at any specific apparent digestibility of fat (say 65%) the efficiency of absorption of Ca increased as the fat content of the diet fed decreased. For example, if the apparent digestibility of fat for all three diets had been 65% the efficiency of Ca absorption for calves fed the HF, MF and LF diets would have been 5%, 29% and 46% respectively.

Fig. 4:3:4 Relationship between apparent absorption of calcium and apparent digestibility of fat by Zebu calves which were approximately 10 weeks of age when fed milk substitutes containing 10%, 20% and 30% added fat during a 5-day balance period.



4:3:5 Absorption of ash (Table 4:3:5)

The efficiency of ash absorption by calves fed the HF diet was less than by calves fed either of the other two diets. Again for any specific level of apparent fat digestibility the efficiency of absorption of ash declines with increasing fat content of the diet fed (Fig. 4:3:5). For example, when apparent digestibility of fat was 65% the efficiency of absorption of ash by calves fed the LF, MF and HF diets was 57%, 49% and 20% respectively.

The level of intake of milk substitute did not appear to affect the efficiency of absorption of ash.

4:3:6 Digestion of organic matter (Table 4:3:6)

As with the absorption of ash, the apparent digestibility of organic matter was less for calves fed the HF diet than for calves fed either of the other two diets. Also the level of intake of the diet did not appear to affect the apparent digestibility of organic matter.

4:3:7 Digestion of nitrogen free extractives (Table 4:3:7)

The apparent digestibility of nitrogen free extractives was very high by calves fed all three diets at both levels of intake, and there is no evidence to suggest any difference in the apparent digestibility of nitrogen free extractives between any of the treatment groups.

Table 4:3:5

Influence of fat level in a milk substitute diet and level of milk substitute intake on excretion and absorption of ash during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Ash intake (g/day)	36.8	33.1	28.0			27.7	37.6		
Ash excreted in faeces (g/day)	5.8	6.0	7.0	0.5	NS	5.8	6.7	0.7	NS
Ash in faecal dry matter (%)	22.2	21.3	19.3	0.9	*	20.2	21.2	0.7	NS
App. absorption of ash (%)	80.1	79.0	69.9	2.2	**	75.8	76.9	2.3	NS

1 to 7 See Table 4:3:1 for explanation

Fig. 4:3:5 Relationship between apparent absorption of ash and apparent digestibility of fat by Zebu calves which were approximately 10 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 5-day balance period.

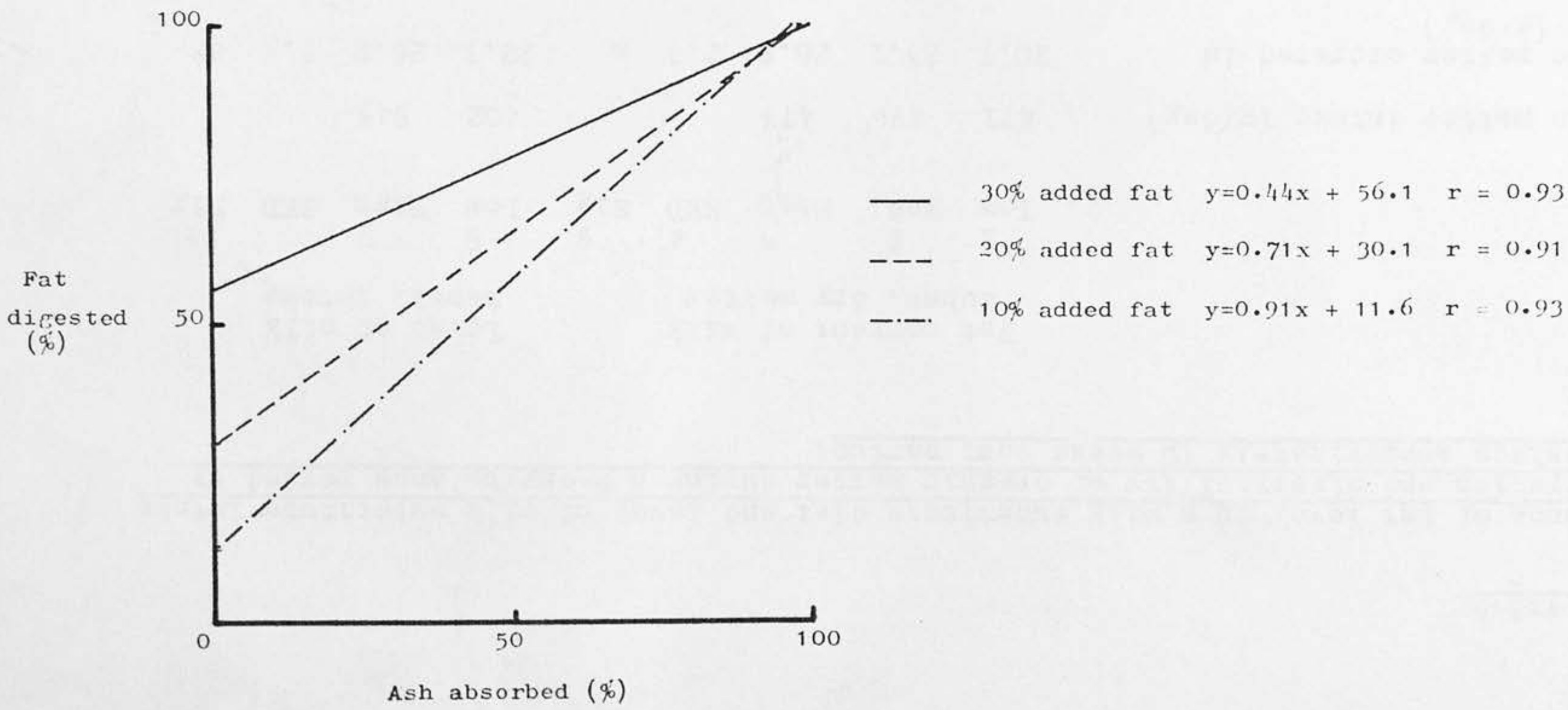


Table 4:3:6

Influence of fat level in a milk substitute diet and level of milk substitute intake on excretion and digestibility of organic matter during a 5-day balance period by Zebu calves approximately 10 weeks post partum.

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Organic matter intake (g/day)	471	476	473			402	545		
Organic matter excreted in faeces (g/day)	20.7	23.1	28.9	2.3	*	22.3	26.2	3.5	NS
App.digestibility of organic matter (%)	94.7	94.4	92.8	0.6	*	93.7	94.2	0.5	NS

1 to 7 See Table 4:3:1 for explanation

Table 4:3:7

Influence of fat level in a milk substitute diet and level of milk substitute intake on excretion and digestibility of nitrogen free extractives (NFE) during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
NFE intake (g/day)	240	217	188			182	248		
NFE excreted in faeces (g/day)	3.9	2.7	3.1	0.5	NS	3.4	3.1	0.1	NS
App. digestibility of NFE (%)	97.8	98.3	97.7	0.3	NS	97.9	98.0	0.2	NS

1 to 7 See Table 4:3:1 for explanation

4:3:8 Energy metabolism (Table 4:3:8)

The apparent digestibility of energy was similar for calves fed the three milk substitute diets. The excretion of energy in urine was, however, significantly lower by calves fed the HF diet than by calves fed the other two diets. The metabolisable energy intake increased with increasing fat content of the diet fed, but the metabolisable energy intake as a percentage of gross energy intake was similar between treatment groups. The level of intake of the milk substitute diet did not appear to affect the efficiency of energy metabolism.

Regressions were calculated to describe the relationship between live weight increase and metabolisable energy intake by Zebu calves fed the three milk substitute diets (Fig. 4:3:6). The metabolisable energy intake when live weight increase was zero was similar, at approximately 1600 kcal/day for calves fed the LF and MF diets, but when live weight increase of calves fed the HF diet was zero, the metabolisable energy intake was 1850 kcal/day. Also, for each kg live weight increase per day, calves fed the LF and MF diets required approximately 2850 kcal of metabolisable energy per day above maintenance, but calves fed the HF diet required

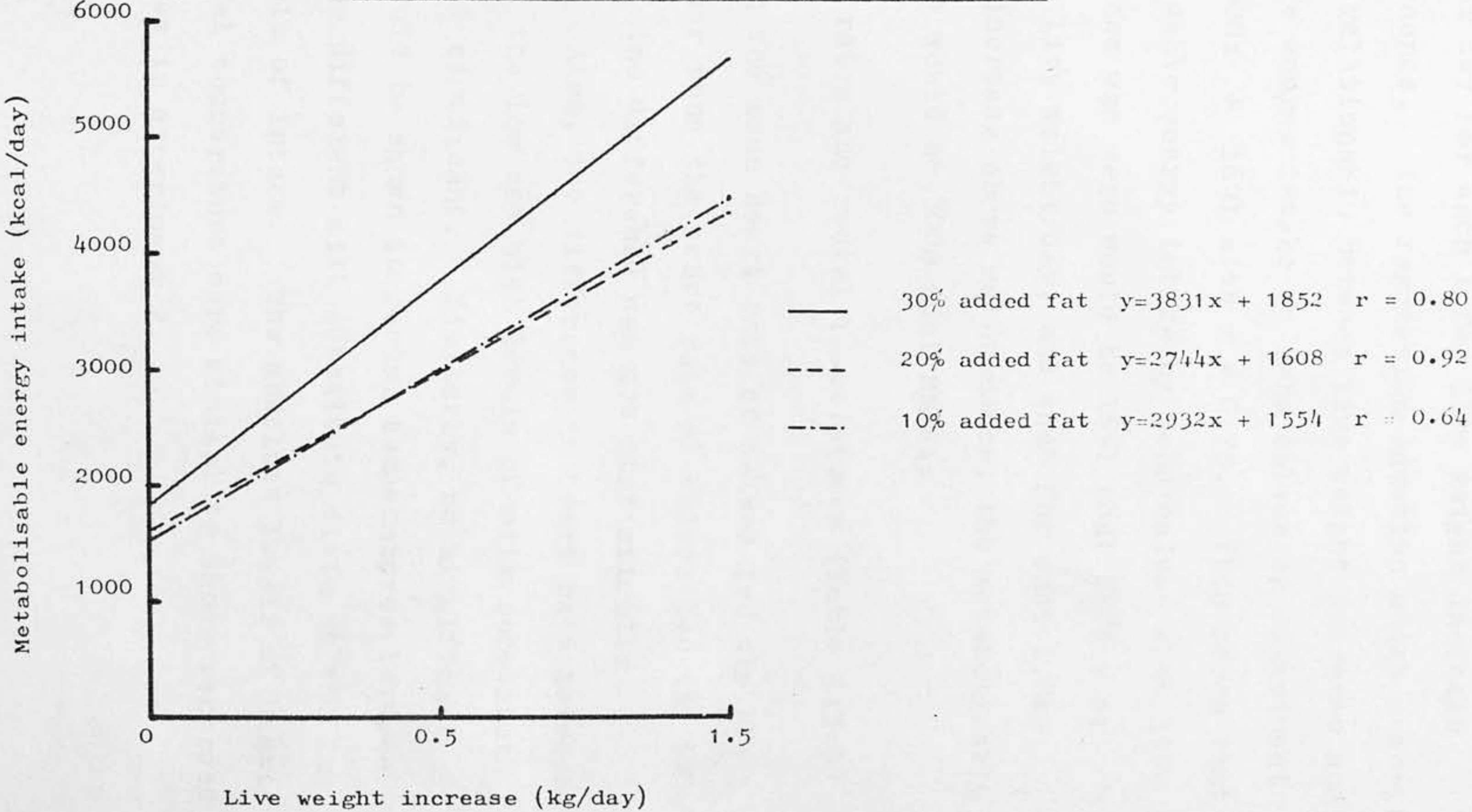
Table 4:3:8

Influence of fat level in a milk substitute diet and level of milk substitute intake on energy metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Gross energy intake (kcal/day)	2411	2647	2847			2238	3032		
Energy excreted in faeces (kcal/day)	150	188	242	18.1	**	177	211	27.0	NS
App. digestibility of energy (%)	92.6	92.0	90.0	1.1	NS	91.1	92.0	0.8	NS
Energy excreted in urine (kcal/day)	62	57	41	7.1	*	48	59	12.3	NS
Metabolisable energy intake (kcal/day)	2199	2402	2563	31	***	2014	2762	641	NS
Metabolisable energy in gross energy intake (%)	91.2	90.7	90.0	1.2	NS	90.0	91.1	6.8	NS

1 to 7 See Table 4:3:1 for explanation

Fig. 4:3:6 Relationship between daily live weight increase and daily metabolisable energy intake by Zebu calves which were approximately 10 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 5-day balance period.



3850 kcal per day for each 1.0kg live weight increase above maintenance. The regression equation which describes the overall relationship between live weight increase and metabolisable energy intake by Zebu calves in experiment 3 was $y = 3008x + 1691$ with $r = 0.78$. This shows that the metabolisable energy intake by Zebu calves when live weight increase was zero would be 1691 kcal ME/day or 52 kcalDE/kg live weight/day, and that for each 1.0kg live weight increase above maintenance, the metabolisable energy intake would be 3008 kcal ME/day

4:3:9 Heart rates and rectal temperatures (Table 4:3:9)

Although the mean heart rate of calves fed the HF diet was higher than the heart rate of calves fed the LF and MF diets, the difference was not statistically significant. Also, the difference in heart rate between calves fed at the low and high levels of milk substitute intake was not significant. Similarly, no significant difference could be shown in rectal temperatures between calves fed the different milk substitute diets at the low and high levels of intake. The absolute levels of heart rate and rectal temperature were similar to those recorded for Zebu calves in experiment 2.

Table 4:3:9

Influence of fat level in a milk substitute diet and level of milk substitute intake on the heart rates and rectal temperatures during a 5-day balance period of Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Heart rate (beats/min)	83	83	87	3.7	NS	80	89	11.5	NS
Rectal temperature (^{O}F)	101.0	100.9	101.1	0.4	NS	100.6	101.3	0.4	NS

1 to 7 See Table 4:3:1 for explanation

4:3:10 Water metabolism (Table 4:3:10)

No difference was observed between any of the treatment groups in any of the parameters measured. The absolute quantities of water intake and urine excreted were higher than those recorded for Zebu calves in experiment 2, but were lower than absolute quantities recorded for Holstein calves in experiment 2.

4:3:11 Calcium metabolism (Table 4:3:11)

Calves fed the HF diet had a lower apparent absorption and retention of Ca than calves fed the MF and LF diets. The level of milk substitute intake did not affect the absorption or retention of Ca. Absorption and retention of Ca was more efficient by Zebu calves in experiment 2 than by the same Zebu calves in experiment 3, presumably because, as was shown in experiment 2, the apparent absorption and retention of Ca decreased with age.

Regressions were calculated to describe the relationship between Ca and N retention by calves fed the different milk substitute diets (Fig. 4:3:7). Irrespective of the diet fed the relationship between Ca and N retention remained similar, each unit increase in N retention corresponding to an increase of 0.21 to 0.28 units in Ca retention. Also, when N retention was zero Ca retention was within the range 0.60 - 1.37 g/day.

Table 4:3:10

Influence of fat level in a milk substitute diet and level of milk substitute intake on water metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Water intake in milk (kg/day)	3.3	3.3	3.2			2.8	3.7		
Voluntary water intake(kg/day)	1.9	1.6	1.4	0.3	NS	1.8	1.5	0.4	NS
Total water intake (kg/day)	5.2	4.9	4.6	0.3	NS	4.6	5.2	1.3	NS
Urine excreted (kg/day)	3.2	3.3	2.9	0.4	NS	3.0	3.3	1.0	NS
Difference (kg/day)	2.0	1.6	1.7	0.2	NS	1.6	1.9	0.3	NS

1 to 7 See Table 4:3:1 for explanation

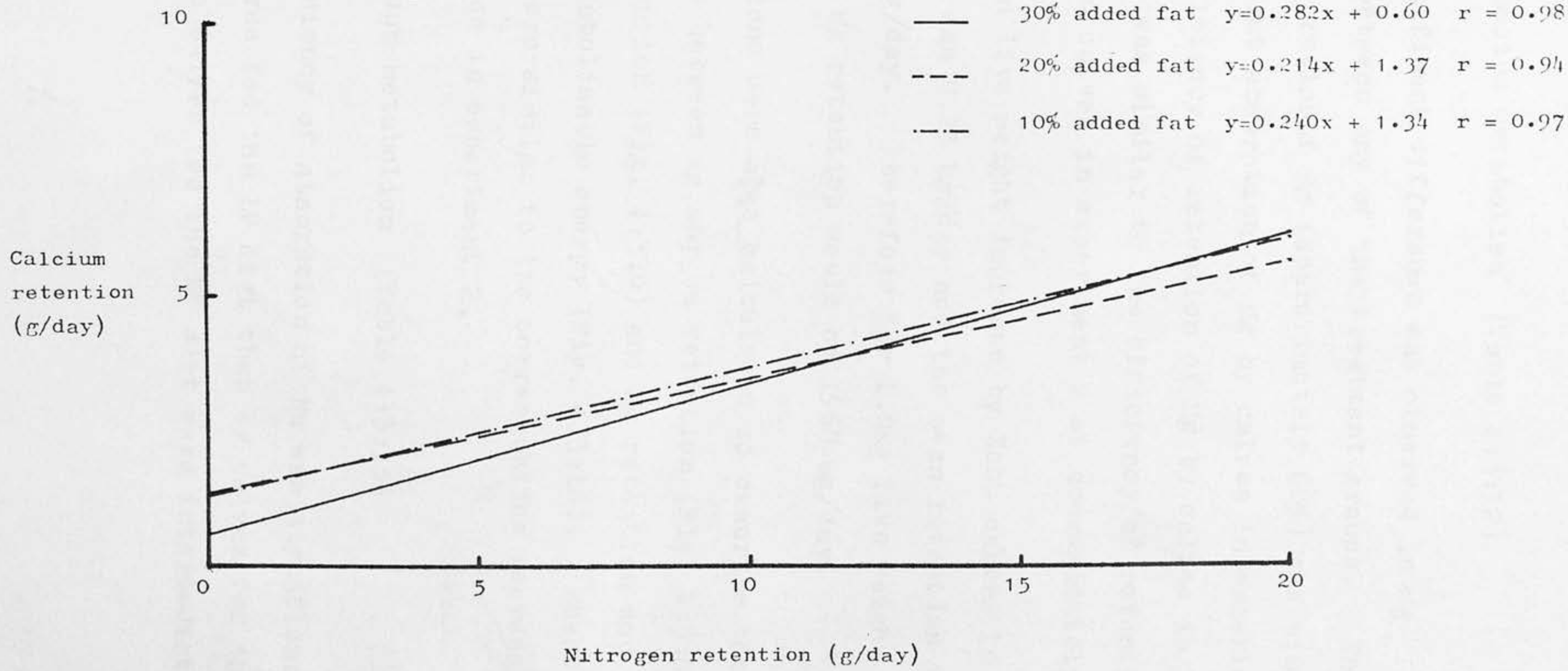
Table 4:3:11

Influence of fat level in a milk substitute diet and level of milk substitute intake on calcium metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Ca intake (mg/day)	5479	5160	4957			4402	5995		
Ca excreted in faeces (mg/day)	1021	1156	1186	73	NS	1147	1094	90	NS
Ca in faecal ash (%)	17.1	18.1	17.3	0.6	NS	18.2	16.9	0.4	NS
Ca excreted in urine (mg/day)	52	40	43	10.2	NS	52	38	5.7	NS
Ca in urine DM (%)	0.17	0.16	0.17	0.03	NS	0.22	0.11	0.03	NS
Total Ca excreted (mg/day)	1073	1196	1229	78	NS	1199	1132	95	NS
Ca excreted in faeces as %age total Ca excreted	93.4	94.7	94.4	1.3	NS	92.0	96.4	2.1	NS
App. absorption of Ca (%)	76.1	73.0	68.7	2.2	*	69.6	75.6	3.2	NS
Ca retention (mg/day)	4407	3965	3728	127	**	3203	4863	1294	NS
Ca retention (%)	75.1	72.2	67.8	2.3	*	68.4	75.0	3.3	NS

1 to 7 See Table 4:3:1 for explanation

Fig. 4:3:7 Relationship between nitrogen and calcium retention by Zebu calves which were approximately 10 weeks of age when fed milk substitute diets containing 10%, 20% and 30% added fat during a 5-day balance period.



4:3:12 Magnesium metabolism (Table 4:3:12)

No significant difference was observed in Mg metabolism between any of the treatment groups. The apparent absorption of Mg (approximately 60%) was similar to the apparent absorption of Mg by calves in experiment 2. The efficiency of retention of Mg by calves in experiment 3 was similar to the efficiency of retention of Mg by Zebu calves in experiment 2 at approximately 50%.

The mean live weight increase by Zebu calves in experiment 3 was 0.23 kg/day and the mean retention of Mg was 359 mg/day. Therefore for 1.0kg live weight increase the Mg retention would be 1560 mg/day.

Regressions were also calculated to describe the relationships between Mg and Ca retention (Fig. 4:3:8) Mg and N retention (Fig. 4:3:9) and Mg retention and intake of metabolisable energy (Fig. 4:3:10). These regressions were similar to the corresponding regressions for Zebu calves in experiment 2.

4:3:13 Sodium metabolism (Table 4:3:13)

The efficiency of absorption of Na was significantly higher by calves fed the LF diet than by calves fed the HF diet, those calves fed the MF diet were intermediate.

Table 4:3:12

Influence of fat level in a milk substitute diet and level milk substitute intake on magnesium metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Mg intake (mg/day)	705	652	636			564	765		
Mg excreted in faeces (mg/day)	240	238	190	32	NS	194	251	63	NS
Mg in faecal ash (%)	4.6	4.3	3.1	0.6	NS	4.3	3.7	0.4	NS
Mg excreted in urine (mg/day)	82	81	85	17	NS	77	88	45	NS
Mg in urine DM (%)	0.2	0.3	0.3	0.05	NS	0.3	0.2	0.08	NS
Total Mg excreted (mg/day)	322	319	275	39	NS	271	339	108	NS
Mg excreted in faeces as %age total Mg excreted	75.1	75.9	71.1	4.3	NS	69.7	78.3	6.7	NS
App. absorption of Mg (%)	60.1	62.1	64.1	7.2	NS	63.3	60.9	0.7	NS
Mg retention (mg/day)	384	333	361	40	NS	293	426	72	NS
Mg retention as %age Mg intake	49.0	51.5	52.6	7.6	NS	49.8	52.3	3.6	NS

1 to 7 See Table 4:3:1 for explanation

Fig. 4:3:8 Relationship between magnesium and calcium retention by Zebu calves which were approximately 10 weeks of age when fed three milk substitute diets containing 10%, 20% and 30% added fat during a 5-day balance period.

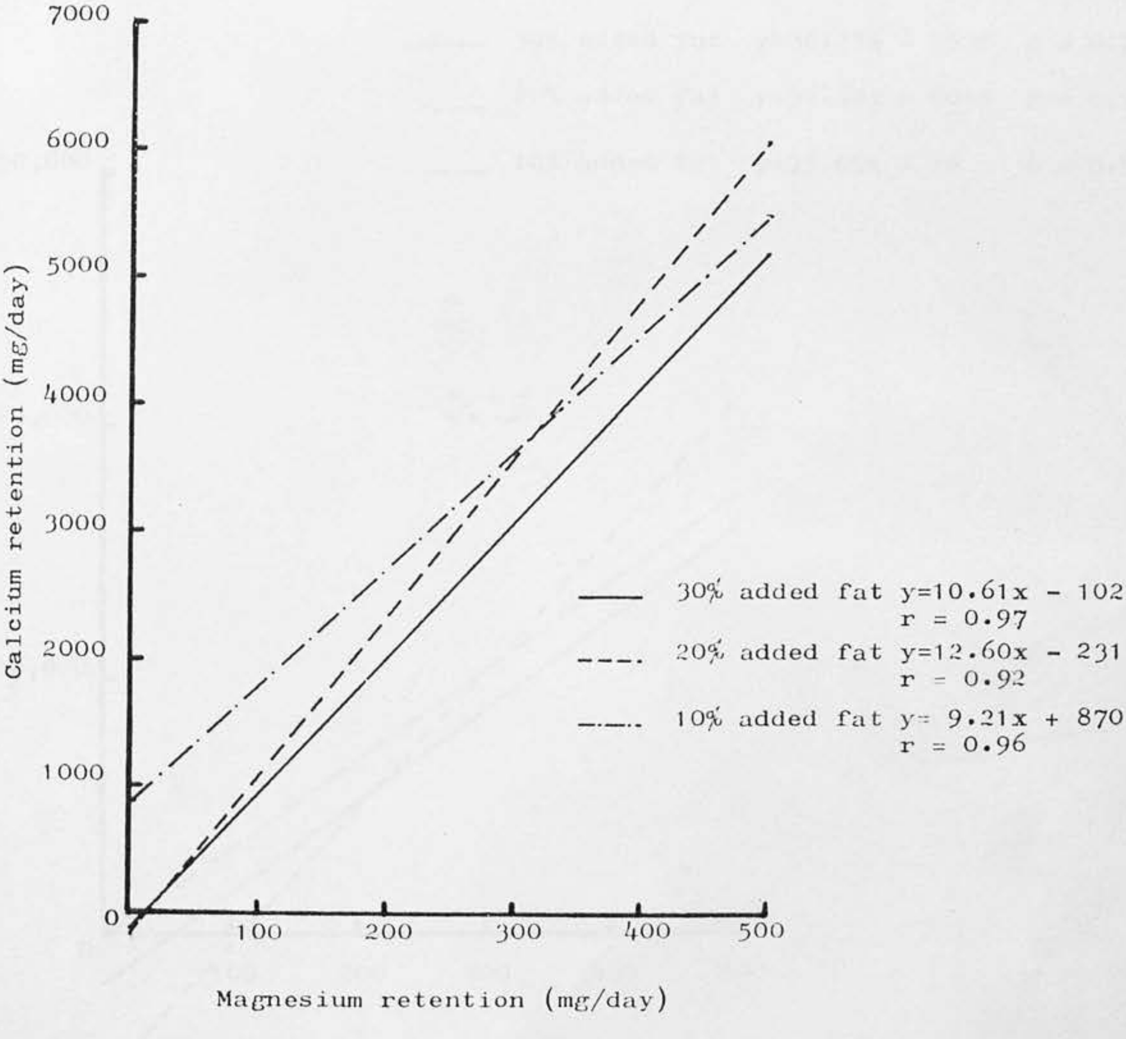


Fig. 4:3:9 Relationship between magnesium and nitrogen retention by Zebu calves which were approximately 10 weeks of age when fed three milk substitute diets containing 10%, 20% and 30% fat during a 5-day collection period.

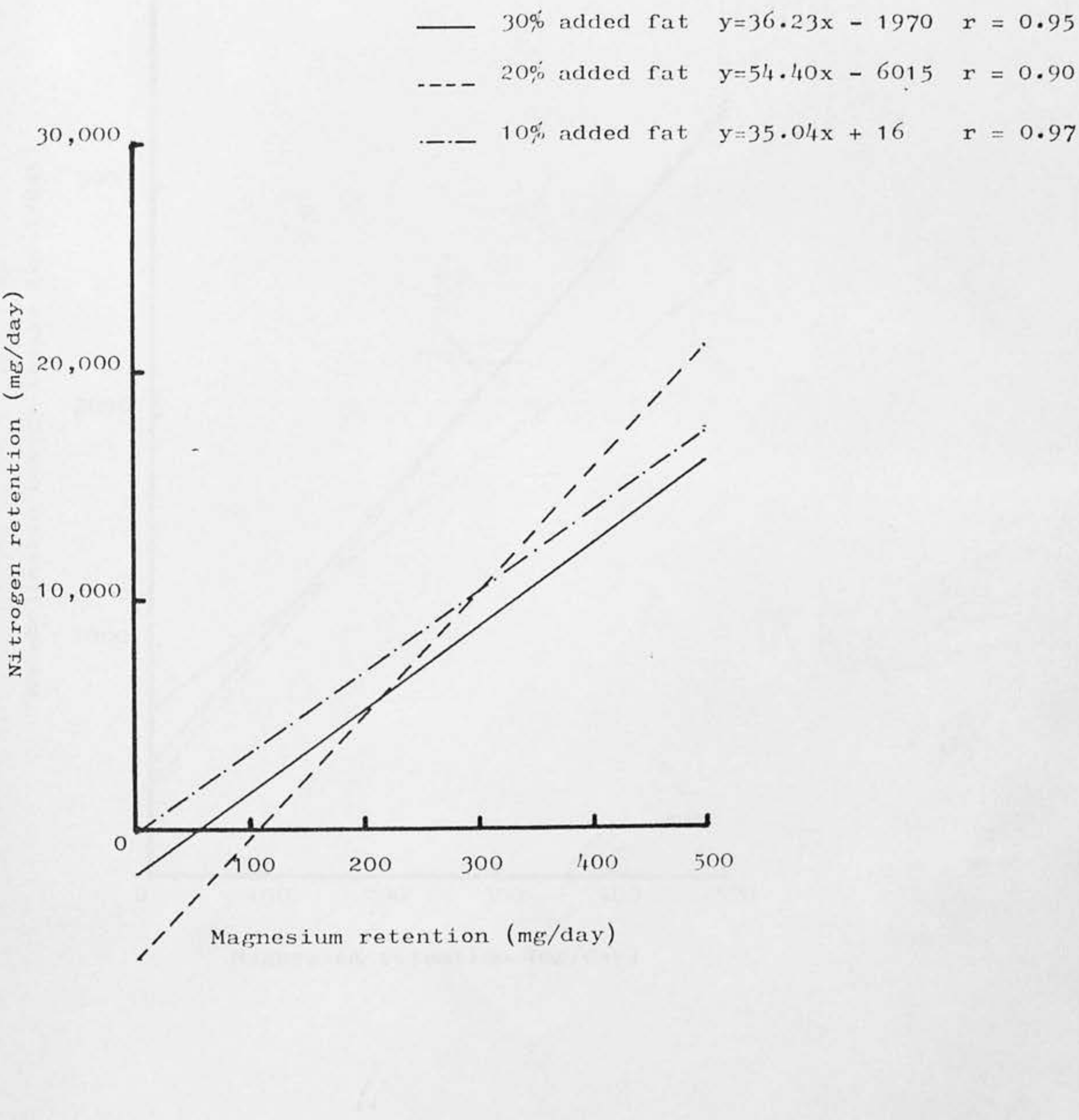


Fig. 4:3:10 Relationship between magnesium retention and metabolisable energy intake by Zebu calves which were approximately 10 weeks of age when fed three milk substitute diets containing 10%, 20% and 30% added fat during a 5-day balance period.

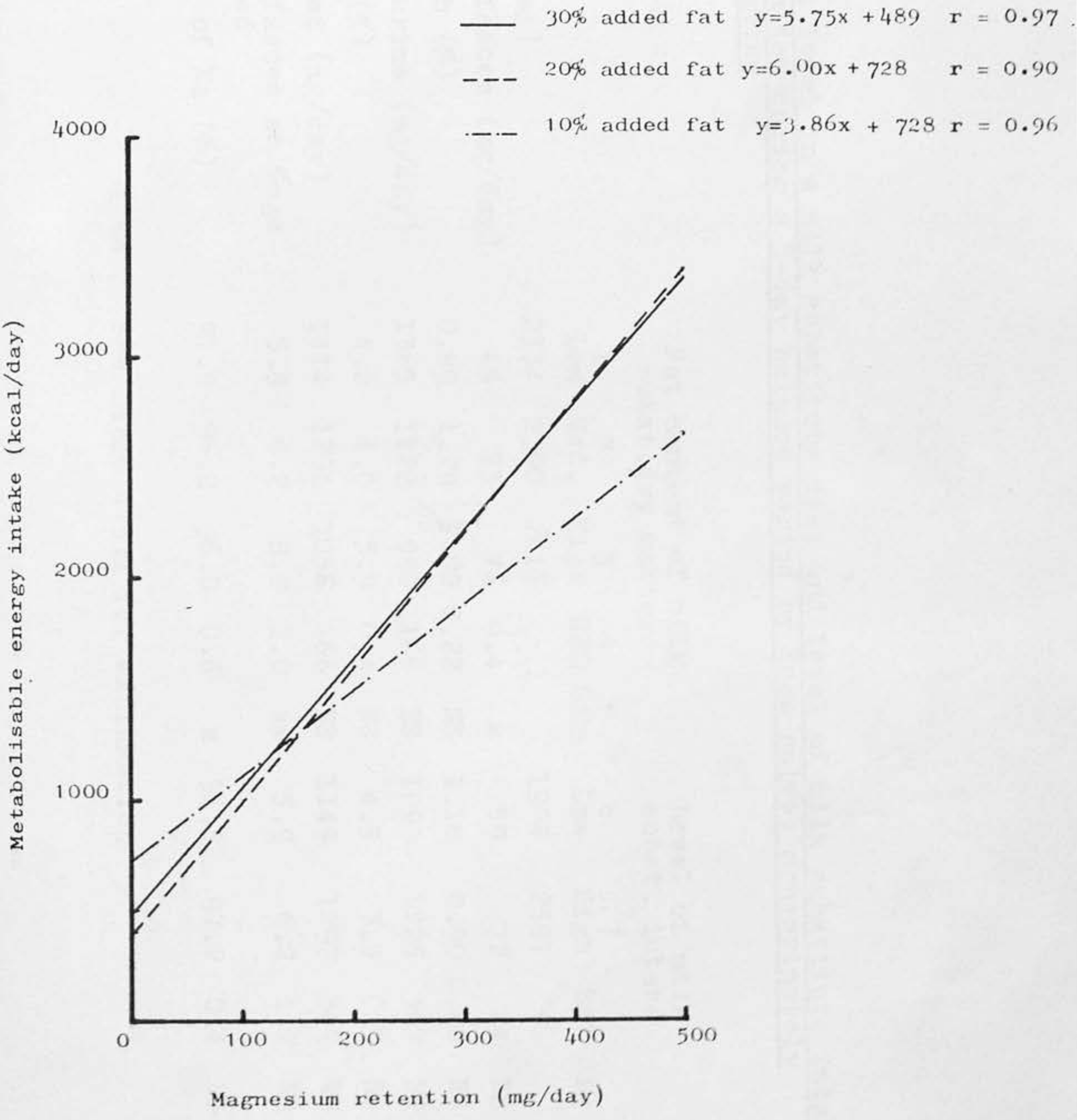


Table 4:3:13

Influence of fat level in a milk substitute diet and level of milk substitute intake on sodium metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst.dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
Na intake (mg/day)	2334	2390	2015			1904	2587		
Na excreted in faeces (mg/day)	49	73	76	9.4	*	59	72	24	NS
Na in faecal ash (%)	0.89	1.28	1.08	0.22	NS	1.18	0.99	0.28	NS
Na excreted in urine (mg/day)	1365	1128	980	165	NS	1090	1225	367	NS
Na in urine DM (%)	4.2	4.0	3.9	0.4	NS	4.5	3.5	0.5	NS
Total Na excreted (mg/day)	1414	1201	1056	166	NS	1149	1297	387	NS
Na excreted in faeces as %age total Na excreted	3.8	6.2	8.2	1.0	**	5.9	6.2	1.2	NS
App. absorption of Na (%)	97.8	96.8	96.0	0.6	*	96.5	97.2	0.4	NS

1 to 7 See Table 4:3:1 for explanation

The trend of decreasing excretion of Na in urine as the fat content of the diet increased, which was noted with calves in experiment 2, was also apparent with Zebu calves in experiment 3, but in experiment 3 the differences between calves fed the different diets were not significant. Therefore, as the level of fat in the diet increased Na excreted in the faeces as a percentage of the total Na excreted also increased.

The level of milk substitute intake did not appear to affect the metabolism of Na.

4:3:14 Potassium metabolism (Table 4:3:14)

Potassium metabolism by calves was very similar to Na metabolism, except that the effect of high levels of fat in the milk substitute diet had a more marked effect on K metabolism than on Na metabolism. The absorption of K was lower by calves fed the HF diet than by calves fed either of the other two diets. As with Na metabolism, K metabolism was not affected by the level of milk substitute intake.

4:3:15 Phosphorus metabolism (Table 4:3:15)

No difference was observed in the absorption of P between calves fed the three milk substitute diets. The absolute retention and efficiency of retention of P was, however, lower for calves fed the HF diet than for calves

Table 4:3:14

Influence of fat level in a milk substitute diet and level of milk substitute intake on potassium metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
K intake (mg/day)	8300	8365	6095			6428	8745		
K excreted in faeces (mg/day)	181	212	282	33.1	*	176	274	19.4	*
K in faecal ash (%)	3.55	3.58	3.89	0.56	NS	3.39	3.96	0.19	NS
K excreted in urine (mg/day)	6777	5919	5293	523	NS	5253	6740	2104	NS
K in urine DM (%)	22.4	21.2	21.4	1.2	NS	21.9	21.5	2.2	NS
Total K excreted (mg/day)	6958	6131	5574	524	NS	5428	7014	2123	NS
K excreted in faeces as %age total K excreted	2.8	3.5	6.2	1.0	*	3.8	4.5	1.4	NS
App. absorption of K (%)	97.7	97.4	94.8	0.8	*	96.9	96.4	1.0	NS

1 to 7 See Table 4:3:1 for explanation

Table 4:3:15

Influence of fat level in a milk substitute diet and level of milk substitute intake on phosphorus metabolism during a 5-day balance period by Zebu calves approximately 10 weeks post partum

	Fat content of milk subst. dry matter					Level of milk subst. intake			
	1 Low	2 Med.	3 High	4 SED	5 Sig	6 Low	7 High	SED	Sig
P intake (mg/day)	4188	4128	3074			3214	4372		
P excreted in faeces (mg/day)	435	392	392	43	NS	436	377	53	NS
P in faecal ash (%)	7.16	5.75	5.28	0.58	*	6.23	5.89	1.07	NS
P excreted in urine (mg/day)	1834	1742	1567	138	NS	1497	1932	476	NS
P in urine DM (%)	6.0	6.6	6.7	0.3	NS	6.3	6.5	0.3	NS
Total P excreted (mg/day)	2269	2134	1960	172	NS	1933	2308	468	NS
P excreted in faeces as %age total P excreted	21.5	17.7	19.8	2.4	NS	20.4	18.9	5.0	NS
App. absorption of P(%)	85.2	87.6	83.0	1.8	NS	83.8	86.7	3.6	NS
P retention (mg/day)	1908	1994	1114	190	**	1281	2063	567	NS
P retention as %age P intake	39.7	43.3	23.1	4.2	**	36.2	34.5	2.0	NS

1 to 7 See Table 4:3:1 for explanation

fed either of the other two diets. The level of milk substitute intake did not appear to affect the P retention.

The absorption and retention of P by calves in experiment 3 was lower than by Zebu calves in experiment 2, which shows that P absorption and retention decreased with increasing age of calves.

4:4 Observations

This section deals with two observations made on Zebu calves which markedly affected the pre-weaning and post-weaning performances of these calves.

Introduction

In addition to the points covered in experimental work already mentioned, two other factors would appear to limit growth rate and production by Zebu calves. These were the influence of the rearing system on voluntary food intake by Zebu calves and the incidence of urolithiasis with Zebu calves post-weaning.

4:4:1 The influence of the rearing system on voluntary food intake by Zebu calves.

The greatest difference between Holstein and Zebu calves in experiment 1 was in the rate of live weight increase. This difference was associated with the level of reconstituted milk intake by the two breeds, which, in turn, was caused by the failure of Zebu calves to adapt to the system of artificial rearing used.

There are three possible reasons why this phenomenon should have occurred with Zebu calves -

1) Poor quality and/ or unsuitable composition of the milk substitute diets fed to the Zebu calves.
2) The appetite for milk of Zebu calves was lower than anticipated.
3) The method of feeding was unsuitable for use with Zebu calves.

It is unlikely that the composition and/or quality of the milk substitute diets affected its ingestion by Zebu calves for the following reasons:

(a) The reluctance by Zebu calves to consume the reconstituted milk substitute diets offered was not related to the fat content of the diets.

(b) After completing experiment 2, two Zebu calves whose intake of reconstituted milk substitute was only sufficient to provide maintenance were offered whole milk, obtained from Holstein cattle, over a period of two weeks, but no increase could be observed in level of milk intake compared with that of reconstituted milk substitute, and the calves did not increase their live weight during this two week period.

(c) The milk substitute diets offered to Zebu calves were identical to those shown to be suitable for Holstein calves in this experiment.

(d) Except for minor differences which have already been noted, the digestion and retention of the proximate fractions of the milk substitute diets ingested by Zebu calves was similar to the digestion and retention of those fractions by Holstein calves.

To investigate whether the low appetite was the reason for the low intake of milk substitute diets by Zebu calves a further three Zebu calves were obtained and were suckled by Holstein nurse cows twice daily for a period of 14 days. This period coincided with collection periods 2 and 3 in experiment 3 for the last three Zebu calves allocated to experiment 3. The intake of milk by the Zebu calves suckled by nurse cows was measured daily by weighing calves before and after sucking and the mean daily intake of milk by these calves was compared with the intake of reconstituted milk substitute by the last three Zebu calves allocated to experiment 3.

On completion of collection period 3, the treatments imposed on these two groups of calves were reversed and the mean daily intake of milk for a further 14-day period was determined for both groups of calves (Table 4:4:1:1).

Table 4:4:1:1

Mean reconstituted milk substitute intake by Zebu calves when artificially reared for a period of 14 days and when suckled by nurse cows for a period of 14 days

No. of calves	Mean daily intake of milk (kg)
3	1.7 (A.R.) followed by 6.4 (S.)
3	7.3 (S.) " " 1.8 (A.R.)

A.R. = artificially reared

S. = suckled

The mean daily live weight changes were also calculated for both groups of calves. (Table 4:4:1:2)

Table 4:4:1:2

Mean daily live weight changes by Zebu calves when artificially reared for a period of 14 days and when suckled by nurse cows for a period of 14 days

No. of calves	Mean daily live weight change (kg)
3	- 0.09 (A.R.) followed by 0.64 (S.)
3	0.68 (S.) " " -0.03 (A.R.)

A.R. = artificially reared

S. = suckled

The mean daily intake of milk and the mean daily growth rate were, therefore, much higher when calves were suckled compared with when they were artificially reared. The milk intake by those calves which were suckled was, in fact, approximately 20% of their birth weight and was, therefore, approximately double the intake of reconstituted milk substitute that Zebu calves in experiment 3 could be encouraged to ingest.

4:4:2 The incidence of urolithiasis with Zebu calves post-weaning

A locally compounded concentrate mixture containing maize meal, coconut meal, wheat middlings, alfalfa meal, meat meal, soya bean meal, molasses and added vitamins was offered ad libitum to Holstein calves on completion of experiment 2 and to Zebu calves on completion of experiment 3. All calves were weaned abruptly from milk substitute diets three weeks after the concentrate ration was offered. One kilogramme of freshly cut grass, predominantly Pangola Grass (Digitaria decumbeus), but also containing small quantities of Para Grass (Brachiaria mutica) and Savannah Grass (Axonopus compressus) was offered to each calf two weeks before weaning.

The mean chemical compositions of the concentrate and grass diets are shown in table 4:4:2:1 and table 4:4:2:2 respectively.

Table 4:4:2:1

Mean Proximate composition of concentrate diet (%)

Dry matter	87.6
Crude Protein in dry matter	19.1
Crude fibre in dry matter	5.3
Ether extract in dry matter	4.5
Ash in dry matter	6.9
Nitrogen free extractives in dry matter	64.2
Calcium in dry matter	1.22
Magnesium in dry matter	0.55
Phosphorus in dry matter	0.98
Potassium in dry matter	1.37
Sodium in dry matter	0.53

Table 4:4:2:2 /

Table 4:4:2:2

Mean proximate composition of grass diet (%)

Dry matter	25.5
Crude protein in dry matter	7.4
Crude fibre in dry matter	30.7
Ether extract in dry matter	1.9
Ash in dry matter	9.8
Nitrogen free extractives in dry matter	50.2

Of a total of 15 Zebu calves used in this work, five died as a result of the formation of urinary calculi. Three of these calves died within three weeks of weaning, the two others died approximately six weeks after weaning. Under identical management no ill health was recorded with any of the 36 Holstein calves used.

Post-mortem examination of the five calves revealed that the urinary bladder had ruptured in two cases and was grossly distended in the other three cases. The calculi ranged in size from about one to ten millimetres and were found throughout the urinary system of all calves. Spicules were also located in preputial hairs of all five calves. In four of the five cases, death followed within 24 hours of the calf showing signs of discomfort, but the fifth animal was moribund for a period of six days before death ensued, and in this animal calculi were found most predominantly in the kidneys, which were enlarged and which had "leukaemia-like"lesions. Extensive haemorrhages were noted in all animals, particularly in the bladder and the spleen.

The symptoms of ill-health exhibited by all five calves were very characteristic. All animals were on an increasing plane of nutrition (their rate of food intake was increasing) and correspondingly their growth rate was improving. The first sign of impending death from calculi formation in each of the calves was that the level of food and water intake decreased by the order of 50% over a period of 24 hours. This situation was followed quickly by the animal becoming moribund and the abdomen becoming tense and painful to the animal when touched. When the animal attempted to urinate an urethral "pulse" immediately below the anus was apparent, and on these occasions the animal was obviously experiencing some considerable pain. In one of the five animals there was also a slight prolapse of the rectum. No faeces or urine was seen to be passed by any of the animals after the symptom of decreased food intake was observed and the first impression is that of a constipated animal. A laxative (castor oil) was, in fact, administered to the first two animals, which eventually died as a result of calculi formation, but this laxative had no effect.

Calculi removed from one of the calves post-mortem were ashed and the magnesium, calcium and phosphorus content of the ash was found to be 37.6%, 1.0% and 0.2% respectively. The major compound in the calculi ash would therefore appear to be an oxide or hydroxide of magnesium.

The rate of concentrate intake by those calves which died as a result of calculi formation ranged from 1.5 to 3.3 kg/day with a mean of 2.1 kg/day immediately before the reduction in food intake took place. The mean intake of dry matter in the form of concentrates by these calves was, therefore, 1.8 kg/day and the magnesium intake 10.08 g/day. It would appear that Holstein calves were able to deal with this level of Mg intake presumably by excreting most of it in the faeces and urine, but Zebu calves because of their low rate of urine excretion compared with Holstein calves (as indicated in experiment 3) were not able to do so. It is also probable that the condition in Zebu calves was precipitated immediately after weaning because of the reduction in total water intake by these calves when the feeding of a milk substitute was stopped.

5: DISCUSSION

Introduction

Little information exists on the digestibility of milk substitute diets by pre-ruminant Bos indicus calves when these calves are artificially reared. Also, while the performance of pre-ruminant Bos taurus calves in a temperate environment is well documented, considerably less information exists on their performance in a tropical environment. The work undertaken for this thesis was designed to provide information on the efficiency of utilisation of nutrients by pre-ruminant Bos indicus calves and close some of the gaps in our existing knowledge of the performance of Bos taurus calves in both a temperate and a tropical environment.

5:1 Voluntary intake of food and calf growth rate

Similar diets were used throughout all of the experiments reported in this thesis, and it has been reported in section 4:4:2 that the inability of Zebu calves to consume the quantities of milk offered does not indicate that the milk substitute diets were unpalatable, but that those Zebu calves used in this work had a peculiar reluctance to accept the diets in the form provided.

With all three Zebu calves which died before weaning, the cause of death was found, on post-mortem examination, to be pneumonia. The most recent publication on mortality in <u>Bos indicus</u> calves is that of Sharma, Jain and Noble (1975). These workers studied the mortality to one year of age using a total of 4896 artificially reared <u>Bos indicus</u> calves of the Tharparkar, Sahiwal and Red Sindhi breeds in India. The mean mortality rate to one year was 17.5% with the greatest losses occurring during the first month of life. Pneumonia was the major cause of death up to six months of age, and accounted for 41% of deaths. The three <u>Bos indicus</u> calves in my work which died before weaning could not be encouraged to consume sufficient milk to even maintain their body weight and all became very weak. This general weakness was possibly a major factor in predisposing these animals to pneumonia. Low voluntary food intake by <u>Bos indicus</u> calves was also found with shorthorned Zebu calves in Uganda where, in one experiment, 61% of the calf deaths were associated with a failure by these calves to drink milk from buckets (Wilson, 1957).

<u>Bos indicus</u> calves can, however, be reared successfully by artificial methods. In previous unpublished work in Tanzania using <u>Bos indicus</u> calves, I compared the growth

rate to three months of age of calves which were artificially reared with calves which were suckled by nurse cows. A total of four experiments were completed in which calves were weaned at three and six months of age. The artificially reared calves were fed whole milk from buckets twice daily and the suckled calves were suckled by nurse cows twice daily, each cow suckling two calves.

The mean daily growth rate to three months of age by calves on each treatment in each of the four experiments is shown in Table 6:1 as a percentage of live weight. This growth rate was obtained by calculating the value of k in the formula $W = Be^{+kt}$ (Roy, 1970a) and multiplying this value of k by 100 (see section 2:1:1).

Table 5:1:1

Mean daily rate of live weight increase as a percentage of live weight between birth and three months of age by artificially reared and suckled Bos indicus calves

Method of feeding	Age of weaning	Exp 1	Exp 2	Exp 3	Exp 4	Mean
Bucket-fed (whole milk)	3 months	0.87	0.92	0.84	0.78	0.85
	6 months	0.86	0.95	0.92	0.92	0.91
Suckled	3 months	0.63	0.85	1.01	0.82	0.83
	6 months	0.84	0.87	0.86	0.93	0.88

The growth rates for artificially reared and suckled calves were similar but they were much lower than the growth rate of 1.5% of live weight per day which has been suggested as the maximum possible by Bos taurus calves (Roy, 1970a). However, the quantity of milk fed to calves which were artificially reared was restricted to 4.5kg/day and the quantity of milk consumed by suckled calves was similar. These growth rates, therefore, do not reflect the growth rate potential of Bos indicus calves but merely indicate that Bos indicus calves when artificially reared can have as good a growth rate as Bos indicus calves which are suckled by nurse cows.

The six Bos indicus calves (mentioned in section 4:4) which were suckled by nurse cows had mean live weights at the beginning and end of the 14-day suckling period of 27.0 kg and 36.2 kg respectively. Part of the live weight increase during the suckling period can be attributed to an increase in the weight of the contents of the alimentary tract. Stobo, Roy and Gaston (1966) reported that with calves of this age the contents of the alimentary tract weighed 6.2% of the animal's live weight. By reducing the mean live weight of calves at the end of the suckling period by 6.2% the mean live weight of 34.0 kg is obtained, and by using this live weight to represent W and the live weight at the beginning of the suckling period to represent B in the formula $W = Be^{+kt}$ the value of k can be calculated as 0.0164. This indicates that the mean daily live weight increase by these suckled _Bos indicus_ calves was 1.64%. The potential for live weight increase by these _Bos indicus_ calves would therefore appear to be as high as the potential for live weight increase reported by Roy (1970a) for _Bos taurus_ calves.

The voluntary intake of milk by these suckled _Bos indicus_ calves of up to 10 kg per day was much greater than that by _Bos indicus_ calves which were artificially reared. This level of milk intake by suckled _Bos indicus_ calves is, in fact, similar to that reported as being the maximum appetite for _Bos taurus_ calves (Wilkinson and Tayler, 1973).

Thus, while some Bos indicus calves can be artificially reared others, because of a behavioural response are difficult to rear artificially. However, the different results obtained in Tanzania and Trinidad with _Bos indicus_ calves may have a simple explanation. Success in rearing _Bos indicus_ calves artificially in Tanzania was attributed to the system of removing calves from their dams immediately after birth. It was found that if the calf was not allowed to suck milk from its dam then it could be trained to drink milk from a bucket more readily than if it was allowed to suck milk from its dam. This system could not be practised with those _Bos indicus_ calves used in Trinidad because calves were obtained from two private farmers who did not keep accurate service records of their herds and who were not prepared to undertake the extra work involved in removing the calf from its dam at birth and feeding it its dam's milk from a bucket for the first three to four days of life. This meant that each calf was allowed to suck milk from its dam for the first three to four days of life before it was transferred to the University of the West Indies.

The system of removing calves from their dams at birth has been practised recently with _Bos indicus_ calves at Naivasha, Kenya, resulting in a similar improvement in the ease with which these calves could be trained to drink milk from a bucket (Wilkins, 1973). The system of artificially rearing _Bos indicus_ calves used successfully by Sayer (1934) also included the separation of calf and dam at birth.

Until more information is available on why _Bos indicus_ calves do not adapt readily to systems of artificial rearing, the general recommendation should be that they be suckled by their dams or by nurse cows. In situations where Bos indicus calves have to be artificially reared then they should be removed from their dams immediately after birth.

It should not be construed that this behavioural phenomenon with Bos indicus cattle is restricted only to this species, because subjective observations would suggest that suckled calves from herds of Bos taurus cattle used for beef production may also be difficult to rear artificially.

5:2 Urolithiasis

The incidence of urolithiasis in Bos indicus cattle in the Mathura district in India has been reviewed by Lavania, Misra and Angelo, (1973) and has been shown to be as high as 75% of the total cattle population. A total of 2322 cases of urolithiasis, one third of which were in animals up to two years of age, was reported by Bhatt, Ahmed and Benares Prasad, (1973) in one region of Gujarat State in India during a three year period. Low water consumption was not thought by these workers to be a contributing factor to this condition solely on the grounds that water was readily available to the animals.

There is no published work on the comparative incidence of urolithiasis in Bos indicus and Bos taurus animals when fed the same diet. The work reported in this thesis apparently indicates that under the conditions of these experiments, Bos indicus calves are more prone to urolithiasis than Bos taurus calves and that the difference in the metabolism of Mg by Bos indicus and Bos taurus calves may be one of the main causal factors of this condition.

Irrespective of the level of Mg intake by Ayrshire pre-ruminant calves it has been reported that a maximum of five per cent of the total excretion of Mg is in the urine (Blaxter and Rook, 1954). In experiment 2, however, 32% and 37% of the total Mg excreted was excreted in urine by Holstein and Zebu calves respectively. These results agree with those of Raven and Robinson (1959) who found that 40% of the total Mg excreted was excreted in urine. The discrepancies between the findings of Blaxter and Rook (1954) and those of myself and Raven and Robinson (1959) may have resulted from the levels of Mg intake by calves used by myself, Raven and Robinson (1959) and Blaxter and Rook (1954). These were 838 mg/day, 695 mg/day and 233 mg/day respectively.

The high rates of excretion of Mg in urine by Holstein and Zebu calves possibly indicate that both Holstein and Zebu calves were excreting as much Mg in urine as they could. The fact that the concentration of Mg in the urine dry matter of both breeds was similar also supports this contention. Because of the greater turnover of water by Holstein calves than by Zebu calves, the absolute excretion rate of Mg in the urine by Holstein calves was double that by Zebu calves.

It was calculated from the data obtained in experiment 2 that if Holstein and Zebu calves both had a live weight increase of 1.0kg/day then the retention of Mg would have been 740 mg/day and 4033 mg/day respectively. This retention of Mg by Holstein calves agrees well with the net requirement of 700 mg for 1.0 kg live weight gain reported by Blaxter and Rook (1954), but the retention of Mg by Zebu calves is much greater and suggests an inability by Zebu calves through insufficient water intake to excrete quantities of Mg in excess of requirements.

Support for the hypothesis that low levels of water intake play an important part in the incidence of urolithiasis is obtained from work in America (quoted by Linzell, 1971) where urolithiasis was prevented in sheep and cattle by increasing the salt content of the diet to 2 - 4% in order to encourage an increase in water intake.

It is doubtful, however, because of the behavioural response by Zebu calves to water intake if the provision of additional dietary salt would induce Bos indicus calves to consume additional quantities of water and a more useful measure of preventing urolithiasis would be to include less Mg in the diet. Under the conditions of this experiment, a concentrate diet whose dry matter contained 0.55% of Mg was too high in Mg for feeding to those Bos indicus calves used in this work.

While the incidence of urolithiasis was higher with Zebu calves than with Holstein calves in Trinidad, it does not necessarily follow that Bos indicus calves are more prone to urolithiasis than Bos taurus calves. If it is assumed that the level of water intake was a major factor in causing urolithiasis then if water intake by Holstein calves had been restricted to the level of water intake by Zebu calves urolithiasis might also have occurred with Holstein calves. Also, the fact that those Holstein calves used in Trinidad had a greater level of water intake than those Zebu calves used in Trinidad, does not necessarily indicate that all breeds of Bos taurus calves would have had an equally high rate of voluntary water intake relative to Bos indicus calves under the conditions of the experiment in Trinidad.

5:3 Nitrogen metabolism

The apparent digestibility of dietary nitrogen was similar by both Holstein and Zebu calves. The endogenous urinary nitrogen loss by Holstein and Zebu calves does, however, appear to be different, the mean value for Holstein calves being 3.3g/day and for Zebu calves 5.5g/day and 6.7g/day in experiments 2 and 3 respectively. From these findings, it can be anticipated that the digestible nitrogen required for maintenance by both breeds of calf would also differ.

Regressions were calculated for the relationship between apparently digested nitrogen ingested and nitrogen retained for both breeds of calf in experiment 2 and for Zebu calves in experiment 3. These are shown in Fig. 5:3:1. Extrapolation of these regression lines to zero nitrogen retention provided an estimate of the mean digestible nitrogen required for nitrogen equilibrium which can be assumed to be the digestible nitrogen requirement for maintenance of body protein. These estimates of digestible nitrogen required for maintenance are shown in Table 5:3:1 together with the estimates of endogenous urinary nitrogen excretion.

Table 5:3:1 /

Fig. 5:3:1 Relationship between apparently digested nitrogen and nitrogen retention by Holstein and Zebu calves fed on milk substitute diets during a 15-day balance period.

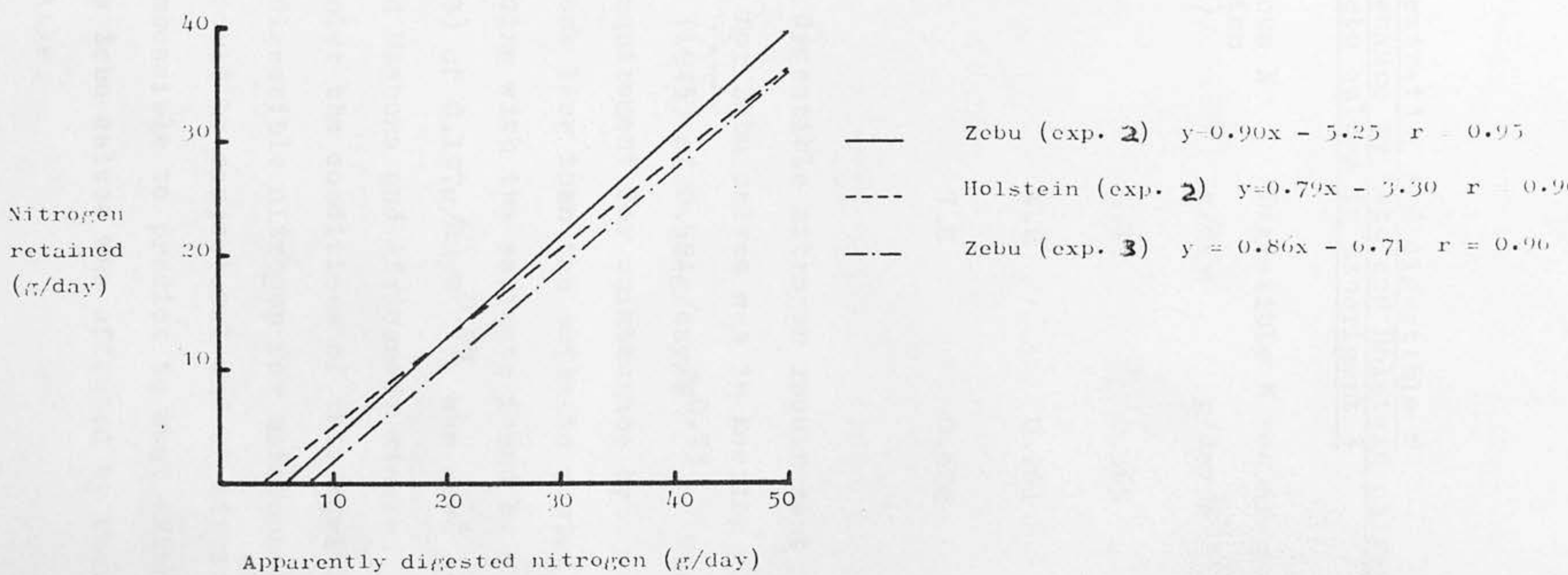


Table 5:3:1

Endogenous urinary N excretion and digestible N requirement for maintenance by Zebu and Holstein calves in experiment 2 and Zebu calves in experiment 3

Breed	Endogenous N excretion (g/day)	Digestible N requirement g/day	g/day/$W^{0.73}$
Zebu (exp 2)	5.5	6.1	0.565
Holstein (exp 2)	3.3	4.2	0.261
Zebu (exp 3)	6.7	7.8	0.608

The estimates of digestible nitrogen requirement for maintenance found for Zebu calves was in keeping with the estimate by Brody (1945) of 0.584g/day/$W^{0.73}$. The digestible nitrogen requirement for maintenance by Holstein calves was much less than the estimate quoted by Brody and more in keeping with the estimate found by Elliott and Topps (1963) of 0.197g/day$W^{0.73}$, who used one, two and three year old Mashona and Africander steers. Any explanation why under the conditions of this work Zebu calves required more digestible nitrogen for maintenance than Holstein calves would be conjectural and of little value because it is impossible to predict to what extent nitrogen metabolism by Zebu calves was affected by their low voluntary food intake.

The reason for the low requirement for digestible nitrogen by Holstein calves was probably because the diets used contained adequate amounts of readily available carbohydrate and fat, and as stated by Elliott and Topps (1963) 'energy-rich diets given to monogastric animals have a protein-sparing effect'.

5:4 Energy requirement for maintenance and production

The mean digestible energy (DE) requirements of Holstein calves for maintenance in experiment 2 (33 kcal DE/kg live weight/day) was much less than the mean digestible energy requirement for maintenance by Zebu calves in experiment 2 (59 kcalDE/kg live weight/day) and experiment 3 (52 kcalDE/kg live weight/day). The mean digestible energy requirement for maintenance by Friesian calves in experiment 1 (46 kcalDE/kg live weight/day) was also higher than that found for Holstein calves in experiment 2.

The estimates obtained for Friesian and Zebu calves are in keeping with the estimate of 52 kcalDE/kg live weight/day suggested by Blaxter and Wood (1951b), but the estimate obtained for Holstein calves is much lower and is more in line with the results of Johnson and Elliott (1972a) in Rhodesia who estimated that the maintenance requirements of Friesland calves was 100.8 kcalME/kgW$^{0.73}$/day. Using the same units the energy requirement for maintenance by Holstein calves in my work was 89.5 kcalME/kgW$^{0.73}$/day. It is difficult to explain why Holstein calves in Trinidad had a lower energy requirement for maintenance than Friesian calves in Scotland, but presumably environmental temperature played a major part with Friesian calves requiring more energy for thermal regulation than Holstein calves. The high energy requirement for maintenance by Zebu calves, relative to Holstein calves in Trinidad is not entirely unexpected in view of the resistance by Zebu calves to 'force-feeding'.

The metabolisable energy (ME) required for 1.0kg live weight increase was 3670 and 3454 kcalME for Holstein and Zebu calves respectively in experiment 2, and is similar to the 3700 kcalDE reported by Bryant, Foreman, Jacobson and McGilliard (1967) but is less than the 4250 kcalME estimated by Johnson and Elliott (1972b). Bryant et al., (1967) used a milk substitute diet containing 18% lard oil (dry matter basis) while Johnson and Elliott (1972b) used whole milk which would have a butterfat content of at least 24% (dry matter basis). In the light of my finding with Holstein calves that those calves fed the low, medium and high fat diets required 3186, 3975 and 4521 kcalME/kg live weight increase the calves used by Johnson and Elliott (1972b) may have deposited more fat in their carcases than those calves used by Bryant et al., (1967).

5:5 Heart rate

The heart rate of calves increased as the fat content of the diet fed increased and as the level of milk substitute intake increased, but decreased with age of calf. Zebu calves appeared to have a lower heart rate than Holstein calves, but this was merely a reflection of the lower food intake by Zebu calves compared with Holstein calves (Table 5:5:1).

Table 5:5:1

The influence of fat content in a milk substitute diet and level of milk substitute intake on the heart rate (beats/min) of Holstein and Zebu calves

Level of fat in diet	Low intake		High intake	
	Holstein	Zebu	Holstein	Zebu
Low	82.6	82.0	103.3	94.7
Medium	80.8	81.8	113.3	91.3
High	94.7	89.0	124.7	92.7

At the low rate of milk substitute intake heart rates of Holstein and Zebu calves were similar, but at the high rate of milk substitute intake the heart rate of Holstein calves was considerably higher than that for Zebu calves because of the greater intake of food by Holstein compared with Zebu calves.

5:6 Level of added fat in milk substitute diets

The milk substitute diets containing 30% added fat were digested less efficiently than milk substitute diets containing either 10% or 20% added fat by all groups of calves with no indication that Zebu calves were able to digest the high fat diet more efficiently than Holstein calves. With the dietary constituents used in this work no advantage is to be gained by increasing the fat content in a milk substitute diet from 20% to 30% of the dietary dry matter.

The apparent digestibility of fat in the milk substitute diet containing 30% added fat was greater by Holstein calves in Trinidad than by Friesian calves in Scotland. Also, the use of this diet in Scotland had to be discontinued because of a high mortality rate in calves fed this diet.

There is one tentative suggestion that can be made as to why the milk substitute diet containing 30% added fat was digested better by Holstein calves in Trinidad than by Friesian calves in Scotland. More water was ingested by Holstein calves than by Friesian calves which would have the effect of increasing the total volume of food ingested and since the rate of passage of chyme from the abomasum is related to the volume of the abomasal contents (Mylrea, 1966) it is conceivable that the passage of chyme from the abomasum to the duodenum was faster in Holstein calves than in Friesian calves, which, in turn, prevented the ulceration of the abomasal mucosa of Holstein calves.

Irrespective of the relative proportions of fat to Ca in the milk substitute diets, there is a close relationship between the apparent digestibility of fat and the apparent absorption of Ca by all calves. Those calves which digest fat efficiently also absorb Ca efficiently and conversely those calves which have a low apparent digestibility of fat also have a low apparent absorption of Ca irrespective of the diet fed. These findings support those of Ternouth, et al., (1974) who fed a milk substitute diet containing 20% fat (on a dry matter basis) to two Ayrshire and three Friesian bull calves and who found that as the apparent Ca absorption increased from 12 to 96% the apparent digestibility of fat also increased from 40 to 95%. They concluded that low Ca absorption resulted from impaired fat digestion rather than the reverse. This conclusion is also valid in my work because Ca intake was similar for calves fed the milk substitute diets containing different levels of added fat. If dietary constituents had been similar for all diets it could be anticipated that the apparent absorption of Ca would be similar for all diets. The fact that apparent absorption of Ca corresponded to the apparent digestibility of fat in the different milk substitute diets suggests that impaired fat digestion resulted in impaired Ca absorption with fatty acids being excreted in the faeces as Ca soaps.

5:7 Alopecia

Partial alopecia was noted between five and eight weeks of age with all Zebu calves fed milk substitute diets. Hair loss was from the muzzle, ears and legs. No alopecia was noted with any of the Holstein animals at this age. The alopecia noted with Zebu calves was similar to that described by Gullickson, Fountaine and Fitch (1947) and normally disappeared, without treatment, after three to four weeks.

5:8 Mineral metabolism

The metabolism of those minerals investigated appears to be similar by Holstein and Zebu calves except for the metabolism of Mg which has been discussed previously.

If it is assumed that 40% of the Mg retained was retained in the soft tissue and 60% in bone (Blaxter and Rook, 1954) the ratios of Ca retention: Mg retention and N retention: Mg retention for Holstein and Zebu calves can be calculated. The ratios Ca retention: Mg retention by Friesian, Holstein and Zebu calves were 11:1, 28:1 and 20:1 respectively, indicating a greater retention of Mg relative to Ca than the ratio 45:1 suggested by Blaxter and Rook (1954) and are similar to the ratio of 18:1 calculated from data supplied by Raven and Robinson (1959).

Also the ratios of N retention: Mg retention by Friesian, Holstein and Zebu calves were 30:1, 142:1 and 86:1 respectively. Except for the ratio obtained for Holstein calves these ratios do not agree with that of 140:1 obtained by Blaxter and Rook (1954) and are more similar to the ratio of 51:1 calculated from data supplied by Raven and Robinson (1959).

Under the conditions of this work, therefore, it would be pointless to attempt to predict the Mg retention from values of Ca and N retention with any degree of accuracy. It would appear that the level of Mg intake is important because as mentioned previously the Mg intake by calves used by myself and Raven and Robinson (1959) was much greater than that by calves used by Blaxter and Rook (1954).

The retention of P has been reported as being about 27% of the N retention by pre-ruminant calves (Mitchell and McClure, 1937) and in other work can be calculated as being 20% of the N retention (Raven and Robinson, 1959). The retention of P by Friesian, Holstein and Zebu calves corresponded to 26%, 14% and 14% of N retention respectively suggesting that more N relative to P was retained by calves in Trinidad than by calves in Scotland.

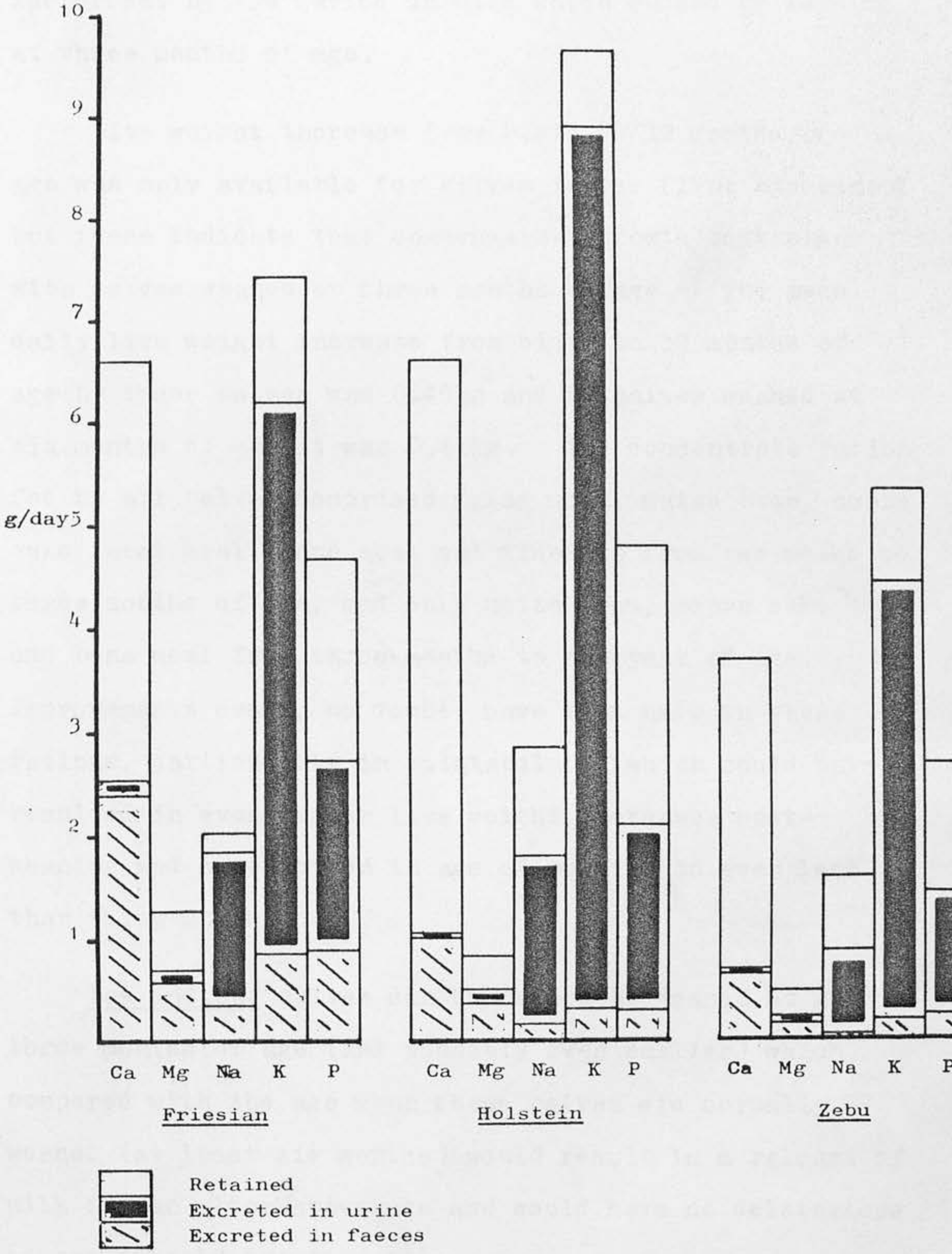
Mitchell and McClure (1937) also suggested that the ratio Ca retention: P retention by pre-ruminant calves was 1.71:1 and this ratio was calculated as 1.77:1 from data supplied by Raven and Robinson (1959). The ratios found with Friesian, Holstein and Zebu calves were 2.06:1, 2.08:1 and 2.46:1 respectively indicating that calves in my work retained more Ca relative to P than did calves in work already published. It would also appear that Zebu calves retained more Ca relative to P than did Friesian or Holstein calves.

The mean daily intake and excretion rates of Ca, Mg, Na, K and P by Friesian, Holstein and Zebu calves are shown diagramatically in Fig. 5:8:1. There was an overall similarity in the excretion and retention rates of these minerals except that Friesian calves excreted more of each mineral in their faeces than did Holstein or Zebu calves. This, however, is merely a reflection of the high excretion rates of these minerals in the faeces by Friesian calves when fed the milk substitute diet containing 30% added fat. The rates of excretion in faeces and urine of the five minerals investigated are all greater than reported values of metabolic faecal loss and endogenous urinary loss of these minerals by pre-ruminant calves.

5:9 Age of weaning Bos indicus calves.

In the previously mentioned work which I carried out in Tanzania, the mean daily live weight increase to six months of age by all calves weaned at three months of age was 0.31kg and by calves weaned at six months of age it was 0.39kg. The mean total milk consumption by calves weaned at three months of age was 280 litres and for those weaned at six months of age it was 630 litres. Therefore, while the live weight increase to six months of age by calves weaned at six months of age was superior

Fig. 5:8:1 Daily intake and excretion rates of Ca, Mg, Na, K and P by Friesian, Holstein and Zebu calves when fed milk substitute diets (g).



to those weaned at three months of age, this superiority was offset by the saving in milk which ensued by weaning at three months of age.

Live weight increase from birth to 12 months of age was only available for calves in the first experiment but these indicate that compensatory growth took place with calves weaned at three months of age. The mean daily live weight increase from birth to 12 months of age by these calves was 0.45kg and by calves weaned at six months of age it was 0.41kg. The concentrate ration fed to all calves comprised maize meal, maize bran, copra cake, meat meal, bone meal and minerals from two weeks to three months of age, and only maize bran, copra cake and bone meal from three months to one year of age. Improvements could, no doubt, have been made in these rations, particularly in palatability, which could have resulted in even higher live weight increases post-weaning and a reduction in age of weaning to even less than three months.

Bos indicus calves can therefore be weaned at three months of age (and possibly even earlier) which, compared with the age when these calves are normally weaned (at least six months) would result in a release of milk for an alternative use and would have no deleterious effect on calf growth rate.

6. SUBJECTS FOR FUTURE INVESTIGATION

1. The difficulties experienced in training Bos indicus calves to drink milk from a bucket should be investigated further to determine, if possible, a specific reason for this phenomenon.

2. Because of various factors, including the low milk production by Bos indicus cows and the difficulties in rearing Bos indicus calves artificially, it is unlikely that the potential for live weight increase by Bos indicus calves has been realised fully. Although there is no reason to assume otherwise, there are no data which indicate that the potential for live weight increase by Bos indicus calves is similar to that for Bos taurus calves. Work should therefore be carried out to determine the potential for live weight increase by Bos indicus calves.

3. In order to prevent the occurrence of urolithiasis in Bos indicus calves, the levels of minerals included in milk substitute and concentrate diets for these calves requires further investigation. Maximum levels at which minerals, especially magnesium, can be included in rations for Bos indicus calves and above which abnormally large quantities of these minerals are retained by these calves should be determined. The effect of the level

of water intake by these calves and by *Bos taurus* calves on the incidence of urolithiasis should also be investigated.

4. The maintenance requirements for digested energy and digested nitrogen appear to be lower for *Bos taurus* calves in Trinidad than for *Bos taurus* calves in Scotland. The influence of environmental temperature on these requirements should be investigated further.

5. The nitrogen metabolism by *Bos indicus* calves requires further investigation in order to determine the effect of level of water and food intake on the metabolism of nitrogen.

6. The influence of environmental temperature on the voluntary water intake and digestibility of a milk substitute diet containing 30% added fat by *Bos taurus* calves should be investigated further.

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8 BIBLIOGRAPHY

BIBLIOGRAPHY

Agricultural Research Council, (1965). The nutrient requirements of farm livestock, No. 2. Ruminants. H.M. Stationery Office, London.

Aitken, J.N., Preston, T.R., Whitelaw, F.G., Macdearmid, A. and Charleson, E.G. (1963). Intensive beef production 2: The effect of three, twelve or sixteen week weaning on the performance of Aberdeen-Angus crossbreds. Anim.Prod., 5, 53.

Anon., (1967) Annual Report on Research and Technical Work, Ministry of Agriculture of Northern Ireland (1967) p. 38.

Antony, W.B. and Starling, J.G. (1968) Adequacy of grazed coastal Bermuda grass for cows nursing calves. J. Anim.Sci., 27, 289.

Ash, R.W. (1964) Abomasal secretion and emptying in suckled calves. J. Physiol., 172, 425.

Bate, W. Espe, D. and Cannon, C.Y. (1946) Influence of homogenization of fat on haircoat of dairy calves. J. Dairy Sci., 29, 41.

Becker, R.B., Eckles, C.H. and Palmer, L.S. (1927) Effect of mineral deficiency on the yield and composition of cow's milk. J. Dairy Sci., 10, 169

Berridge, N.J., Davis, J.G., Kon, P.M., Kon, S.K. and Spratling, F.R. (1942-44) The production of rennet from living calves. J. Dairy. Res., 13, 145.

Bhatt, G.A., Ahmed, S.A. and Benares Prasad (1973) Studies on incidence and physiological chemistry of urinary calculi in bovines. Ind. Vet. J., 50, 459.

Black, A. and Voris, L. (1934) A statistical study of the relationships between the constituents of milk. J. Agric. Res., 48, 1025.

Blackwood, J.H., Morris, S. and Wright, N.C. (1936) The nutritive value of raw and pasteurised milk for calves. The assimilation and retention of nitrogen, phosphorus and calcium. J. Dairy Res., 7, 228.

Blaxter, K.L. (1952) The nutrition of the young Ayrshire calf. 6. The utilisation of energy in whole milk. Br.J. Nutr., 6, 12.

Blaxter, K.L. and Howells, A. (1951) The nuttrition of the young Ayrshire calf. 2. A spirometer for the determination of the respiratory exchange of the calf. Br. J. Nutr., 5, 25.

Blaxter, K.L. and Wood, W.A. (1951a) The nutrition of the young Ayrshire calf. 1. The endogenous nitrogen and basal energy metabolism of the calf. Br. J. Nutr., 5, 11.

Blaxter, K.L. and Wood, W.A. (1951b). The nutrition of the young Ayrshire calf. 3. The metabolism of the calf during starvation and subsequent realimentation. Br.J.Nutr., 5, 29.

Blaxter, K.L. and Wood, W.A. (1952a) The nutrition of the young Ayrshire calf. 5. The nutritive value of cow's whole milk. Br.J.Nutr., 6, 1.

Blaxter, K.L. and Wood, W.A. (1952b) The nutrition of the young Ayrshire calf. 7. The biological value of gelatin and of casein when given as the sole source of protein. Br.J.Nutr., 6, 56.

Blaxter, K.L. and Wood, W.A. (1953) Some observations on the biochemical physiological events associated with diarrhoea in calves. Vet.Rec., 65, 889.

Blaxter, K.L. and Rook, J.A.F. (1954) Experimental magnesium deficiency in calves. 2. The metabolism of calcium, magnesium and nitrogen and magnesium requirements. J. comp. Path.Ther., 64, 176.

Brisson, G.J., Cunningham, H.M. and Haskells, S.R. (1957) The protein and energy requirements of young dairy calves. Can. J. Anim. Sci., 37, 157.

Brody, S. (1945a) Bioenergetics and Growth. New York: Reinhold Publishing Corp. p. 507.

Brody, S. (1945b) Bioenergetics and Growth. New York: Reinhold Publishing Corp. p. 476.

Brookes, A.J. and Vincent, L.S. (1950) Beef production experiment at Cambridge. Interim report. J. Roy. Agric. Soc., 111, 99.

Bryant, J.M., Foreman, C.F., Jacobson, N.L. and McGilliard, A.D. (1967) Protein and energy requirements of the young dairy calf. J. Dairy Sci., 50, 1645

Castle, M.E. and Watson, J.N. (1959) A comparison between early weaning and a more conventional system of rearing dairy calves. Anim.Prod., 1, 31

Chagas, E.C., Riggs, J.K., Smith, J.C. and Cooper, R.J. (1966) Rotational crossbreeding for beef production. J. Anim. Sci., 25, 264.

Chieffi, A., Andreasi, F. and Veiga, J.S. (1950). A comparison of the growth of Zebu cattle born during the dry and rainy seasons. Rev. Fac. Med. vet. S. Paulo, 4, 315.

Colvin, B.M. and Ramsay, H.A. (1968) Soy flour in milk replacers for young calves. J. Dairy Sci., 51, 898.

Colvin, B.M. and Ramsay, H.A. (1969) Growth of young calves and rats fed soy flour treated with acid or alkali. J. Dairy Sci., 52, 270.

Comline, R.S. and Titchen, D.A. (1951) Reflex contraction of the oesophageal groove in young ruminants. J. Physiol., 115, 210.

Converse, H.T. (1949) Circ. U.S. Dep. Agric. no. 822. After Roy, J.H.B. (1970) 'The Calf' Iliffe, London. Vol. 2 p. 100.

Crighton, J.A., Aitken, J.N. and Boyne, A.W. (1959) The effect of plane of nutrition during rearing on growth, production, reproduction and health of dairy cattle. Anim. Prod., 1, 145.

Cunningham, H.M. and Loosli, J.K. (1954) The effect of fat-free diets on young dairy calves with observations on metabolic faecal fat and digestion coefficients for lard and hydrogenated coconut oil. J. Dairy Sci., 37, 453.

Cunningham, H.M., Haskell, S.R., Miles, V.J., Logan, V.S. and Brisson, G.J. (1958) Further studies on the protein and energy requirements of young dairy calves. Can. J. Anim. Sci., 38, 33.

David, J.G. and McDonald, F.J. (1953) Richmond's Dairy Chemistry. Griffin London. p. 16.

DeAlba, J., Munoz, H. and Edwards, C. (1963) Weaning weight and weight gains in beef cattle. Turrialba, 13, 164.

De Rouen, T.M., Reynolds, W.L. and High, J.W. (Jr.) (1963) Evaluation of the Sindhi breed for beef at the Iberia Station. J. Anim. Sci., 22, 243.

De Rouen, T.M., Reynolds, W.L. and Meyerhoeffer, D.C. (1967) Mortality of beef calves in the Gulf Coast Region. J. Anim. Sci., 26, 202.

Dollar, A.M. and Porter, J.W.G. (1957) Utilization of carbohydrates by the young calf. Nature, Lond., 179, 1299.

Drewry, K.J., Brown, C.J. and Honea, R.S. (1959) Relationships among factors associated with mothering ability in beef cattle. J. Anim. Sci., 18, 938.

Duncan, C.W. and Huffman, C.F. (1934) The effect of daily massive doses of viosterol upon calcium and phosphorus metabolism and blood calcium and inorganic phosphorus in calves. J. Dairy Sci., 17, 83.

Ellenberger, H.B., Newlander, J.A. and Jones, C.H. (1950) Variations in the calcium and phosphorus contents of cow's milk. Univ. Vermont Agric. Exp. Stat. Bull. 556.

Elliott, R.C. and Topps, J.H. (1963) Studies of protein requirements of ruminants. 1. Nitrogen balance trials on two breeds of African cattle given diets adequate in energy and low in protein. Br. J. Nutr., 17, 539.

F.A.O. (1973) 1972 Production Year Book, No. 26, F.A.O., Rome.

Galukande, E.B., Mahadevan, P. and Black, J.G. (1962) Milk production in East African Zebu cattle. Anim. Prod., 4, 329.

Garrett, O.F. and Overman, O.R. (1940) Mineral composition of colostral milk. J. Dairy Sci., 23, 13.

Garton, G.A. (1963) The composition and biosynthesis of milk lipids. J. Lipid Res., 4, 237.

Gifford, W. (1949) Importance of high milk production in beef cows over estimated. J. Anim. Sci., 8, 606.

Gifford, W. (1953) Records of the performance of beef cattle in breeding herds; milk production of dams and growth of calves. Ark. Agric. Exp. Sta. Bull 531.

Golding, J., Mackintosh, J. and Mattick, E.V.C. (1935) Investigations on the milk of a typical herd of Shorthorn cows (2). J. Dairy Res., 6, 6.

Gomorri, G. (1942) Practical Clinical Biochemistry by H. Varley, P. 448. Fourth Edition. William Heinemann, London.

Gonzales-Jiminez, E. and Blaxter, K.L. (1962) The metabolism and thermal regulation of calves in the first month of life. Br. J. Nutr., 16, 199.

Gooden, J.M., Branden, M.R., Hartmann, P.E. and Lascelles, A.K. (1972) Factors affecting lipid output and flow of thoracic duct lymph in newborn calves. Aust. J. biol. Sci., 24, 1309.

Gorrill, A.D.L. and Thomas, J.W. (1967) Body weight changes, pancreas size and enzyme activity, and proteolytic enzyme activity and proetin digestion in intestinal contents from calves fed soy bean and milk protein diets. J.Nutr., 92, 215.

Gorrill, A.D.L., Thomas, J.W., Stewart, W.E. and Morrill, J.L. (1967) Exocrine pancreatic secretion by calves fed soybean and milk protein diets. J.Nutr., 92, 86.

Groenewald, J.W. (1935) The influence of rations low in certain minerals on the composition of blood and milk of cows, and on the blood of their progeny. Onderstepoort J.Vet.Sci., 4, 93.

Grosskopf, J.F.W. (1965) Studies on salivary lipase in young ruminants. Onderstepoort, J. vet.Res., 32, 153.

Gueguen, L. and Mathieu, C.M. (1965) Utilization of mineral elements in rations of calves. 2. Influence of calcium - phosphorus level. Ann. Zootech, 14, 231.

Gullickson, T.W., Fountaine, F.C. and Fitch, J.B. (1942) Various oils and fats as substitutes for butter-fat in the ration of young calves. J. Dairy Sci., 25, 117.

Gunstone, F.D. (1967) An introduction to the chemistry and biochemistry of fatty acids and their glycerides. 2nd Edn.London: Chapman and Hall Ltd.

Hansard, S.L., Comar, C.L. and Plumlee, M.P. (1954) The effect of age upon calcium utilization and maintenance requirements in the bovine. J. Anim. Sci., 13, 25.

Hansson, A. (1948) Studies on monozygous cattle twins. 10. The effect of feeding excessive amounts of calcium and phosphorus to milking cows. Acta Agric. suecana, 3, 59.

Hare, J.H., Schwartz, D.P. and Weise, S.J. (1952) The amino acid composition of the fat globule membrane protein of milk. J. Dairy Sci., 35, 615

Henschel, M.J., Hill, W.B. and Porter, J.W.G. (1961) The development of proteolytic enzymes in the abomasum of the young calf. Proc. Nutr. Soc., 20, xl.

Henschel, M.J., Hill, W.B. and Porter, J.W.G. (1963) Carbohydrate digestion in the small intestine of the young steer. Proc. Nutr. Soc., 22, v.

Herald, C.T., Brunner, J.R. and Bass, S.T. (1957) A spectrographic analysis of two protein fractions of the fat-globule membrane of normal cow's milk. J. Dairy Sci., 40, 446.

Heyns, H. (1959) Birth weight of beef cattle important. Fmg. S. Afr., 35, 19.

Heyns, H. (1960) The growth of the Africander calf in relation to the production of the milk of the dam. S.Afr.J.Agric.Sci., 3, 349.

Huber, J.T. (1969) Development of the digestive and metabolic apparatus of the calf. J. Dairy Sci., 52, 1303.

Huber, J.T., Jacobson, N.L., Allen, R.S. and Hartman, P.A. (1961) Digestive enzyme activites in the young calf. J. Dairy Sci., 44, 1494.

Huber, J.T., Jacobson, N.L., McGilliard, A.D. and Allen, R.S. (1961) Utilization of carbohydrates introduced directly into the omaso-abomasal area of the stomach of cattle of various ages. J. Dairy Sci., 44, 321.

Huber, J.T., Jacobson, N.L., McGilliard, A.D., Morrill, J.L. and Allen, R.S. (1961) Digestibilities and diurnal excretion patterns of several carbohydrates fed to calves by nipple pail. J. Dairy Sci., 44, 1484.

Huber, J.T., Rifkin, R.J. and Keith, J.M. (1964) Effect of level of lactose upon lactase concentrations in the small intestines of young calves. J. Dairy Sci., 47, 789.

Huff, J.S., Waugh, R.K. and Wise, G.H. (1951) Effect of glycerol-mono-stearate on fat absorption, growth and health of calves. J. Dairy Sci., 34, 1056.

Hughes, G.P., Alder, F.E. and Redford, R.A. (1955) The overwintering of beef stores. Emp. J. Exp. Agric., 23, 145.

Jacobson, N.L. (1968) Energy and protein requirements of the calf. J. Dairy Sci., 52, 1316.

Jacobson, N.L., Allen, R.S. and Bell, M.R. (1951) The effect of various feeding systems on growth and certain blood constituents of dairy calves. J. Anim. Sci., 10, 1050.

Johnston, P.T.C. and Elliott, R.C. (1972a) Dietary energy intake and utilization by young Friesland calves. 1. The energy and dry matter content of calves at four days of age. Rhod. J. agric. Res., 10, 119.

Johnson, P.T.C. and Elliott, R.C. (1972b) Dietary energy intake and utilization by young Friesland calves. 2. Digestibility and metabolizable energy contents of whole milk and spray-dried skim milk powder, and energy retentions of calves given these foods. Rhod.J.agric.Res., 10, 125.

Joshi, N.R., McLaughlin, E.A. and Phillips, R.W. (1957) Types and breeds of African cattle. Agric. Stud. No. 37. FAO: Rome

Kassab, S.A. (1964) On maternal and some other influences on birth weight, growth and hair coat in two Dutch cattle breeds. Anim. Breed. Abs., 32, 2828.

Kastelic, J., Bentley, O.G. and Phillips, P.H. (1950) Studies on growth and survival of calves fed semi-synthetic milks from birth. J. Dairy Sci., 33, 725.

Kemp, A., Deijs, W.B., Hemkes, O.J. and vanEs, A.J.H. (1961) Hypomagnesaemia in milking cows: intake and utilization of magnesium from herbage by lactating cows. Netherlands J. Agric.Sci., 9, 134.

Kesler, E.M., Ronning, M. and Knodt, C.B. (1951). Some physical characteristics of the tissue and contents of the rumen, abomasum and intestines in male Holstein calves of various ages. J. Anim. Sci., 10, 969.

Kleiber, M. and Luick, J.R. (1956) Calcium and phosphorus transfer in intact dairy cows. Ann. N.Y. Acad.Sci., 64, 299.

Kohli, M.L., Suri, K.R., Bhatnager, U.K. and Kumar, S. (1962) Study of growth in Hariana calves. Indian J. Dairy Sci., 15, 52.

Kondrey, V.E. (1964) Whole milk replacers in calf rearing. 'Kolos' publishing house, Moscow. After Roy, J.H.B. (1970) 'The Calf'. Iliffe, London. Vol. 2. p. 102.

Kretchmer, N. (1973) Food. Freeman and Co., San Francisco. p. 35.

Kullman, L.R., Furr, R.D. and Nelson, A.B. (1961) Creep feeds and creep-feeding fall calves until spring vs. weaning. J. Anim.Sci., 20, 399.

Lambert, M.R., Jacobson, N.L., Allen, R.S. and Zaletal,J.H. (1954) Lipid deficiency in the calf. J. Nutrs., 52, 259.

Lampkin, K. and Lampkin, G.H. (1960) Studies on the production of beef from Zebu cattle in East Africa. II. Milk production in suckled cows and its effect on calf growth. J. Agric. Sci., 55, 233.

Larsen, H.J., Stoddart, G.E., Jacobson, N.L. and Allen,R.S. (1956) Digestion and absorption of various carbohydrates posterior to the rumino-reticular area of the youhg bovine. J.Anim.Sci., 15, 473.

Lassiter, C.A., Brown, L.D., Grimes, R.M. and Duncan,C.W. (1963) Effect of protein level in milk replacers on growth and protein metabolism of dairy calves. J. Dairy Sci., 46, 538.

Lavania, J.P., Misra, S.S. and Angelo, S.J. (1973) Repair of ruptured bladder in a calf - A clinical case. Ind. Vet. J., 50, 477.

Leech, F.B., Macrae, W.D. and Menzies, D.W. (1968) Calf Wastage and Husbandry in Britain. HM Stationery Office, London.

Linzell, J.L. (1971) The U.F.A.W. Handbook on the care and management of farm animals. Longman, London, p. 91.

Lovell, R. and Hill, A.B. (1940) A study of the mortality rate of calves in 335 herds in England and Wales (together with some limited observations in Scotland) J. Dairy Res., 11, 225.

Lowry, J.H. (1970) World Population and Food Supply. Arnold. London. p. 110.

Luick, J.R., Boda, J.M. and Kleiber, M. (1957) Some biokinetic aspects of calcium metabolism in dairy cows. Am. J. Physiol., 189, 483.

McCormick, R.J. and Stewart, W.E. (1967) Pancreatic secretion in the bovine calf. J. Dairy Sci., 50, 568.

McDonald, P., Edwards, R.A. and Greenhalgh, J.F.D. (1966) Animal Nutrition. Oliver & Boyd Ltd., Edin. p.161.

Mahadevan, P. (1965) Dairy cattle breeding in East Africa. E. Afr. agric. For. J., 30, 320.

Mahadeven, P. (1966) Population and production characteristics of red Sindhi cattle in Ceylon. J. Dairy Sci., 38, 1231.

Marples, H.J.S. (1963) The birth weights and gains in weight to six months of age of Ugandan cattle. E. Afr. agric. For. J., 29, 39.

Mason, I.L. and Maule, J.P. (1960) The indigenous livestock of Eastern and Southern Africa. Comw. Bur. Anim. Breed. Gen.Tech. Comm. No. 14. Comw. Agric. Bur.: Farnham Royal.

Mathieu, C.M. and de Tugny, H. (1965) Annls Biol. anim. Biochim. Biophys., 5, 21. after Roy, J.H.B. (1970) 'The Calf' Iliffe, London. Vol.2 p. 100.

Mattoso, J. (1961) Aspects of the growth of Zebus at Uberaba Experimental Breeding Farm. Experientia 1, 65.

Maynard, L.A. and Loosli, J.K. (1956) 'Animal Nutrition' McGraw-Hill Book Company, Inc. p. 288.

Melton, A.A., Cartwright, T.C. and Nelson, L.A. (1967) Cow size as related to efficiency of calf gain. J. Anim. Sci., 26, 206.

Meyer, F. (1958) Birth weight and successful calf rearing. Tierzuchter 10, 167.

Meyn, K. (1970) Beef Production in East Africa. Weltforum-Verlag. 8 Munchen 19. HubertusstraBe 22 p. 80.

Mitchell, H.H. and McClure, F.J. (1937) Mineral nutrition of farm animals. Bull. natn. Res. Coun., Wash. no. 99.

Mochrie, R.D. and Murley, M.R. (1957) Changing dairy calves onto all dry feed at an early age. J. Anim. Sci., 16, 1079.

Montsma, G. (1960) Observations of milk yield and calf growth rate and conversion rate on three types of cattle in Ghana. Trop. Agric., Trin., 37, 293.

Morrill, J.L., Jacobson, N.L., McGilliard, A.D. and Hotchkiss, D.K. (1965) Use of a re-entrant ileal fistula to study carbohydrate utilization by the young bovine. J. Nutr., 85, 429.

Morrison, F.B. (1956) Feeds and Feeding 22nd Edn. Morrison, Ithaca, New York.

Mortenson, F.N., Espe, D.L. and Cannon, C.Y. (1935) Effect of heating milk on the time which the curds remain in the abomasum of calves. J. Dairy Sci., 18, 229.

Munro, H.N. (1951) Carbohydrate and fat as factors in protein utilisation and metabolism. Physiol. Rev., 31, 449.

Mylrea, P.J. (1966) Digestion in young calves fed whole milk _ad lib_. and its relationship to calf scours. Res.vet. Sci., _7_, 407.

Nelms, G.E. and Bogart, R. (1956) The effect of birth weight, age of dam and time of birth on suckling gains of beef calves. J. Anim. Sci., _15_, 662.

Neville, W.E. (Jr.) (1962) Influence of dam's milk production and other factors on 120- and 240-day weight of Hereford calves. J.Anim.Sci., _21_, 315.

Nickerson, T.A. (1960) Chemical composition of milk. J. Dairy Sci., _43_, 598.

Niemann, P.J. and Heydenrych, H.J. (1965) Some environmental and physiological factors affecting birth and weaning weights of beef calves. Anim. Breed. Abs., _34_, 147.

Noller, C.H. and Dickson, I.A. (1953) Value of hay and rumen inoculation in early weaned calves. J. Dairy Sci., _36_, 582.

Noller, C.H., Ward, G.M., McGilliard, A.D., Huffman, C.F. and Duncan, C.W. (1956) The effect of age of calf on the availability of nutrients in vegetable milk replacer rations. J. Dairy Sci., _39_, 1288.

Norton, C.L. and Eaton, H.D. (1946) Dry calf starters for dairy calves. Cornell Agric. Exp.Sta. Bull. 835.

Okamoto, J., Thomas, J.W. and Johnston, T.L. (1959) Utilization of various carbohydrates by young calves. J. Dairy Sci., _42_, 920.

Otterby, D.E., Ramsay, H.A. and Wise, G.H. (1964) Lipolysis of milk fat by pregastric esterase in the abomasum of the calf. J. Dairy Sci., 47, 993.

Ottersby, D.E. and Rust, J.W. (1965) Effects of age and diet on rumen and blood components of the young calf. J. Dairy Sci., 48, 1716.

Owen, E.C. (1952) Bone as a mineral reserve. Br. J. Nutr., 6, 415.

Parpia, H.A.B. (1968) After Lowry, J.H. (1970)

Parsons, D.J. (1958) Problems of increasing livestock production in intensive farming areas of Uganda. E. Afr. Agric. For. J., 23, 167.

Patureau-Mirand, P., Prugnaud, J. and Pion, R. (1974) Effect of sulphur amino acid supplements to a milk replacer on amino acids in blood. Estimation of methionine requirement of pre-ruminant calves. Nutr. Abstr. Rev., 44, 659.

Pilgrim, G.E. (1947) J. Linnaen Soc. (Zoology), 41, 272. after Payne, W.J.A. (1970) Cattle Production in the Tropics. Longman. London. p. 31.

Porter, J.W.G. (1969) Digestion in the pre-ruminant animal. Proc. Nutr. Soc., 28, 115.

Preston, T.R. (1956) Dry feeding of calves. Agriculture (London), 62, 462.

Preston, T.R. (1958) The nutrition of young animals. Proc. Nutrs. Soc., 17, 63.

Preston, T.R. (1960) Unpublished data cited in Preston, T.R. and Willis, M.B. (1970) Intensive Beef Production, Pergamon, Oxford, p. 270.

Preston, T.R. and Ugarte, J. (1974) The rearing of dairy calves by restricted suckling. A personal communication.

Preston, T.R. and Willis, M.B. (1970a). Intensive beef production. Pergamon Press, Oxford p. 237.

Preston, T.R. and Willis, M.B. (1970b) Intensive Beef Production. Pergamon, Oxford. p. 263.

Quale, P.D. (1958) A study of the effects of dietary aureomycin and methods of weaning in early weaned calves. J.Agric.Sci., 50, 335.

Quinones, M. and Preston, T.R. (1968) Early weaning of dairy calves with different quantities of whole milk and with or without alfalfa in the diet. Rev. Cubana Cienc. Agric., 2, 191.

Radostits, O.M. and Bell, J.M. (1968) Nutrient digestibility by new-born calves fed milk replacer. Can. J. Anim. Sci., 48, 293.

Ranasay, H.A. (1962) Electrophoretic characterization of pregastric esterase from the calf. J. Dairy Sci., 45, 1479.

Randel, P.F. (1966) A comparison of whole milk vs. milk replacer and of weaning at 6 or 9 weeks in raising dairy calves. Puerto Rica Agric. Exp. Sta. Bull. 198.

Raven, A.M. (1970) Fat in milk replacers for calves. J. Sci. Fd. Agric., 21, 352.

Raven, A.M. and Robinson, K.L. (1958) Studies of the nutrition of the young calf. A comparison of starch, lactose, and hydrogenated palm oil, with butterfat in milk diets. Br.J. Nutr., 12, 469.

Raven, A.M. and Robinson, K.L. (1959) Studies of the nutrition of the young calf. 2. The nutritive value of unhydrogenated palm-kernel oil, and butterfat, as additions to a milk diet. Br. J. Nutr., 13, 178.

Raven, A.M. and Robinson, K.L. (1960) Studies of the nutrition of the young calf. 3. A comparison of unhydrogenated palm-kernel oil, hydrogenated palm kernel oil, and butterfat, as constituents of a milk diet. Br. J. Nutr., 14, 135.

Raven, A.M. and Robinson, K.L. (1961) Comparative effects of wet and dry feeding on the utilisation of protein by calves, Nature, Lond., 192, 1256.

Raven, A.M. and Robinson, K.L. (1964) Factors affecting the nutritive value of fat for calves. 1. The mode of incorporation into milk diets. J. Sci. Fd. Agric. 15, 214.

Riek, R.F. (1954) The influence of sodium salts on the closure of the oesophageal groove in calves. Aust. vet. J., 30, 29.

Ritzman, E.G. and Colovos, N.F. (1943) Techn.Bull. New Hamps. agric. Exp. Stn. no. 80. after Roy, J.H.B. (1970) 'The Calf' Iliffe, London. Vol. 2 p. 22.

Robinson, C.H., Hlynka, l. Herman, F.A. and McArthur, J.W. (1947) Calcium content of fluid milk. Can. J. Pub. Health, 38, 236.

Rojas, J., Schweigert, B.S. and Rupel, I.W. (1948) The utilisation of lactose by the dairy calf fed normal or modified milk diets. J. Dairy Sci., 31, 81.

Rose, C.J., Christie, G.J. and Conradie, A.P. (1963) The effect of early weaning on the reproductive efficiency of ranch cattle in Southern Rhodesia. Proc. Wld. Conf. Anim. Prod. 3, 125.

Roy, J.H.B. (1959) Scientific Principles of Feeding Farm Livestock. Farmer and Stock-breeder Publications Ltd., London. p. 48.

Roy, J.H.B. (1964) The nutrition of intensively-reared calves. Vet. Rec., 76, 511.

Roy, J.H.B. (1967) Some nutritional and physiological factors affecting the growth and development of the young calf. Acta Universitatis Agriculturae 36, 325.

Roy, J.H.B. (1969) Diarrhoea of nutritional origin. Proc.Nutrs.Soc. 28, 160.

Roy, J.H.B. (1970a) The Calf. Iliffe, London. Vol.1 p.28.

Roy, J.H.B. (1970b) The Calf. Iliffe, London. Vol.2 p.6

Roy, J.H.B. (1970c) The Calf. Iliffe, London. Vol.2 p.30

Roy, J.H.B. (1970d) The Calf. Iliffe, London. Vol.2.p.34

Roy, J.H.B. (1970e) The Calf. Iliffe, London. Vol.2p.101

Roy, J.H.B. (1970f) The Calf. Iliffe, London. Vol.1 p. 60

Roy, J.H.B. (1970g) The Calf. Iliffe, London. Vol.2.p.24

Roy, J.H.B. (1970h) The Calf. Iliffe, London. Vol.2. p.8.

Roy, J.H.B. (1970j) The Calf. Iliffe, London. Vol.2 p.19

Roy, J.H.B. (1970k) The Calf. Iliffe, London. Vol. 2 p.5

Roy, J.H.B. (1974) Problems in the nutrition of the pre-ruminant calf. Proc. Nutr. Soc., 33, 79.

Roy, J.H.B., Gaston, H.J., Shillam, K.W.G., Thompson, S.Y., Stobo, I.J.F. and Greatorex, J.C. (1964) The nutrition of the veal calf. The effect of anaemia and of iron and chlortetracycline supplementation on the performance of calves given large quantities of whole milk. Br.J.Nutr., 18, 467.

Roy, J.H.B., Huffman, C.F. and Reineke, E.P. (1957) The basal metabolism of the newborn calf. Br. J. Nutr., 11, 373.

Roy, J.H.B., Hullam, K.W.G., Thompson, S.Y. and Dawson, D.A. (1961) The effect of emulsification of a milk-substitute diet by mechanical homogenization and by the addition of soya bean lecethin on plasma lipid and Vitamin A levels and on the growth rate of the new-born calf. Br. J. Nutr., 15, 541.

Roy, J.H.B., Stobo, I.J.F., Gaston, H.C. and Greatorex, J.C. (1970) Nutrition of the veal calf. 2. The effect of different levels of protein and fat in milk substitute diets. Br. J. Nutr., 24, 441.

Roy, J.H.B., Stobo, I.J.F. and Gaston, H.J. (1970) The nutrition of the veal calf. 3. A comparison of liquid skim milk with a diet of reconstituted spray-dried skim-milk powder containing 20% margarine fat. Br. J. Nutr., 24, 459.

Saiduddin, S., Riesen, J.W., Graves, W.E., Tyler, W.J. and Casida, L.E. (1967) Effect of suckling on the interval from parturition to first estrus in dairy cows. J. Anim. Sci., 26, 950.

Sayer, W. (1934) Feeding and handling experiments on the Pusa pedigree Sahiwal herd, 1932-33. Agriculture and Live-stock in India, 4, 105.

Schinckel, P.G. and Short, B.F. (1961) The influence of nutritional level during pre-natal and early post-natal life on adult fleece and body characters. Aust. J. Agric. Res., 12, 176.

Schultz, M.O. (1955) Effects of malnutrition in early life on subsequent growth and reproduction of rats. J. Nutr., 56, 25.

Shannon, A.D. and Lascelles, A.K. (1967) A study of lipid absorption in young milk-fed calves with the use of a lymphatico-venous shunt for the collection of thoracic duct lymph. Aust. J. biol. Sci., 20, 669.

Shannon, A.D. and Lascelles, A.K. (1969) Composition and output of lipid in the thoracic duct lymph of the newborn calf. Aust. J. biol. Sci., 22, 189.

Sharara, H.A. (1956) Retention of calcium and phosphorus in Egyptian Domiati cheese. Ind. J. Dairy Sci., 9, 17.

Sharma, K.N.S., Jain, D.K. and Noble, D. (1975) Calf mortality in pure and crossbred Zebu cattle and Murrah buffaloes reared artificially from birth. Anim. Prod., 20, 207.

Shaw, R.H., Woodward, T.E. and Norton, R.P. (1918) Digestion of starch by the young calf. J. Agric. Res., 12, 575.

Shillam, K.W.G. and Roy, J.H.B. (1963) The effect of heat treatment on the nutritive value of milk for the young calf. 5. A comparison of spray-dried skim milks prepared with different pre-heating treatments and roller-dried skim milk, and the effect of chlortetracycline supplementation of the spray-dried skim milks. Br. J. Nutr., 17, 171.

Siddons, R.C. (1968) Intestinal disaccharidases in the calf. Proc. Nutrs. Soc., 27, 18A.

Siewart, K.L. and Otterby, D.E. (1968) Lipolysis of milk fat by pregastric esterase _in vivo._ J. Dairy Sci., 51, 1305.

Skjervold, H. (1967) Some impressions of cattle breeding in Israel. Anim. Breed. Abstr., 35, 198.

Smith, R.H. (1957) Calcium and magnesium metabölism in calves. Plasma levels and retention in milk-fed calves. Biochem. J., 67, 472.

Smith, R.H. (1959) Calcium and magnesium metabolism in calves. 3. Endogenous faecal excretion and absorption of magnesium. Biochem. J., 71, 306.

Stobbs, T.H. (1967) Management of small East African Zebus in relation to milk yield, calf growth and mortality. E. Afr.Agric.For. J. 32, 250.

Stobo, I.J.F., Roy, J.H.B. and Gaston, H. (1966) Rumen development in the calf. 1: The effects of diets containing different proportions of concentrates to hay on rumen development. Br J. Nutr., 20, 171.

Stobo, I.J.F., Roy, J.H.B. and Gaston, H.J. (1967) The effect of different levels of protein and fat in milk substitute diets for veal production. Anim. Prod., 9, 267.

Ternouth, J.H., Siddons, R.C. and Toothill, J. (1971) Pancreatic secretion of the milk-fed calf. Proc. Nutrs. Soc. 30, 89A.

Ternouth, J.H., Roy, J.H.B., Stobo, I.J.F., Ganderton, P., Gillies, C.M. and Shotton, S.M. (1974) The effect of experimental variation in the quantity of pancreatic secretion on the digestion and utilization of milk-substitute diets by the calf. Br. J. Nutr., 32, 37.

Ternouth, J.H., Roy, J.H.B. and Siddons, R.C. (1974) Concurrent studies in the flow of digesta in the duodenum and of exocrine pancreatic secretion of calves. 2. The effects of addition of fat to skim milk and of 'severe' preheating treatment of spray-dried skim-milk powder. Br.J.Nutr., 31, 13.

Thomke, S. (1963a) The digestibility of whole milk vs. milk substitutes containing bone fat or a tallow-lard mixture for calves. Dairy Sci. Abs., 26, 79.

Thomke, S. (1963b) Digestibility of bone fat and beef tallow each of two different particle sizes. Dairy Sci. Abs., 26, 181.

Toothill, J. (1975) The absence of lipolytic activity in the abomasal (gastric) secretion of the pre-ruminant calf. Proc. Nutrs. Soc. 34, 20A.

Torres, J.R. (1962) Genetic correlations between weights and rates of gain in Zebu calves. Experiential 2, 445.

Turner, W.A., Kane, E.A. and Hale, W.S. (1932) Calcium and phosphorus metabolism in dairy cows. 5. The relative assimilation of calcium from grades 1 and 3 Timothy hay. J. Dairy Sci., 15, 267.

van Weerden, E.J. and van Hellemond, K.K. (1967) Protein content of artificial milk preparations for fattening calves. Landbouwk Tijdschr.,79,327

Velu, J.G., Gardner, K.E. and Kendall, K.A. (1959) Utilization of various sugars by the young dairy calf. J. Dairy Sci., 42, 920.

Velu, J.G., Kendall, K.A. and Gardner, K.E. (1960) Utilization of various sugars by the young dairy calf. J. Dairy Sci., 43, 456.

Wadsworth, J.C. and Shannon, A.D. (1971) Effect of whole-milk and replacement-milk feeding on the fatty acid composition of lymph lipids in young calves. Aust. J. biol. Sci., 24, 797.

Walker, D.M. and Faichney, G.J. (1964) Nutritional diarrhoea in the milk-fed lamb and its relation to the intake of sugar. Br. J. Nutr., 18, 209.

Wardrop, I.D. (1966) The effects of the plane of nutrition in early post-natal life on the subsequent growth and development of cattle. Aust. J. agric. Res., 17, 375.

Webster, J. (1930) The ruminant reflex in the ox. Vet. J., 86, 401.

Webster, C.C. and Wilson, P.N. (1966a) Agriculture in the Tropics. Longmans, London, p. 321.

Webster, C.C. and Wilson, P.N. (1966b) Agriculture in the Tropics. Longmans, London. p. 389

Weijers, H.A. and van de Kamer, J.H. (1965) Alteration of intestinal bacterial flora as a cause of diarrhoea. Ntr. Abstr. Rev., 35, 591.

Whitelaw, F.G., Preston, T.R. and Ndumbe, R.D. (1961) The nutrition of the early-weaned calf. 1. The effect on nitrogen retention of diets containing different levels of groundnut meal. Anim. Prod., 3, 121.

Whiting, F. and Clark, R.D. (1955) Raising dairy calves with a limited amount of milk. Can. J. Anim. Sci., 35, 454.

Widdowson, E.M. and Kennedy, G.C. (1962) Rate of growth, mature weight and life-span. Proc. Roy. Soc., B. 156, 96.

Wilkins, J.V. (1973) Personal communication.

Wilkinson, J.M. and Tayler, J.C. (1973) Beef Production from Grassland. Butterworth, London. p. 41.

Williams, E. and Bunge, V.A. (1952) Development of the Zebu herd of Bukedi cattle at Serere, Uganda. Emp. J. Exp. Agric., 20, 142.

Wilson, F. (1963) Calvings and calf mortality in Ankole Long-horned cattle. E.Afr.Agric.For.J., 29, 178.

Wilson, P.N. (1957) Further notes on the development of the Serere herd of Shorthorned Zebu cattle. Emp. J. exp. Agric., 25, 263.

Wiltbank, J.N. and Cook, A.C. (1958) The comparative reproductive performance of nursed cows and milked cows. J. Anim. Sci., 17, 640.

Winchester, C.F. and Ellis, N.R. (1956) Delayed growth of beef cattle. Techn. Bull. U.S. Dep. Agric. No. 1159.

Winchester, C.F. and Howe, P.E. (1955) Relative effects of continuous and interrupted growth in beef steers. Tech. Bull. U.S. Dep. Agric. No. 1108.

Witt, M., Walter, E. and Rappen, W.H. (1964) Investigations on the effect of various factors on birth weight and the relationship between birth weight and weight at 6 and 12 months in Black Pied cattle. Anim. Breed. Abs., 32, 2833.

Xenoulis, P.K., Jacobson, N.L., Young, J.W., McGilliard, A.D. and Allen, R.S. (1967) Digestion and metabolism of sucrose in young milk-fed calves. J. Anim. Sci., 26, 933.

APPENDIX

Plate 1. Feeding a Zebu calf on a milk substitute diet from a bottle.

Plate 2. Alopecia exhibited by a Zebu calf.

Plate 3. Two Zebu calves aged six weeks - the larger was suckled by a nurse cow and the smaller was artificially reared.

Plate 4. An artificially reared Holstein calf and an artificially reared Zebu calf both aged eight weeks which had similar birth weights.

Plate 5. Ulceration of the abomasal mucosa of a Friesian calf fed on a milk substitute diet containing 30% added fat.

Plate 6. Distended bladder of a Zebu calf which died as a result of urolithiasis.

Plate 7. Ruptured bladder of a Zebu calf which died as a result of urolithiasis.

Plate 8. A calculus in the kidney of a Zebu calf which died as a result of urolithiasis.

Plate 1.

Plate 2.

Plate 3.

Plate 4.

Plate 5.

Plate 6.

Plate 7.

Plate 8.